Respiratory health in the past: a bioarchaeological study of chronic maxillary sinusitis and rib periostitis from the Iron Age to the Post Medieval Period in Southern England

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Abstract

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Respiratory disease has affected human populations throughout our history and remains a significant cause of morbidity and mortality today. In spite of this, there is a dearth of bioarchaeological research on this important subject. Previous research has suggested a relationship between poor air quality and the prevalence of chronic maxillary sinusitis and rib periostitis. These conditions have many causes (e.g. congenital disorders, allergies, poor air quality, climate, infectious disease). Chronic maxillary sinusitis and rib periostitis are recognised as bone formation and/or destruction, indicating long-term inflammation of the soft tissues of the sinuses and ribs in some upper and lower respiratory tract conditions.

If air quality is a significant contributor to respiratory disease, the highest prevalence rates would be expected in populations exposed to high concentrations of indoor and outdoor pollutants. This study examines 12 skeletal samples from cemeteries located in southern England, ranging in date from the Iron Age to the Post Medieval Period. The samples were chosen to examine both synchronic and diachronic trends in respiratory disease, contrasting contemporaneous populations living in rural and urban contexts, as well as populations from high and low social status groups. A total of 1203 individuals were examined for this study. Of these, 1101 had at least one sinus preserved, and of these individuals, 546 (49.6%) had sinusitis in one or both sinuses. A total of 2091 sinuses were recorded. Of these, 854 (40.8%) had chronic maxillary sinusitis. 50.42% of 720 males and analysed had sinusitis and 47.85% of 372 females (not significant). Prevalence rates ranged from 30.6% (Post Medieval) to 75.44% (Iron Age) for chronic maxillary sinusitis and 1.59% (Iron Age) to 29.7% (Post Medieval) for rib periostitis, but, when combining the skeletal and archaeological/historical data, the hypothesis posed is not consistently supported. Based on archaeological evidence for lifestyle and housing, these results suggest that the causes of respiratory disease are more complex than this current hypothesis presumes.

RESPIRATORY HEALTH IN THE PAST

A Bioarchaeological Study of Chronic Maxillary Sinusitis and Rib Periostitis from the Iron Age to the Post Medieval Period in Southern England

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1 Introduction

1.1 Introduction

Respiratory disease is a well known illness and cause of death in living populations, but there has been minimal research examining this condition in archaeological populations, primarily because the respiratory system is predominantly made up of soft tissue, and most bioarchaeologists examine skeletal remains (Smith *et al.* 2004). However, inflammation of these soft tissues caused by irritation or infection can cause lesions to form on the underlying bone, leaving macroscopically visible traces for researchers to examine (Roberts 2007).

Due to the lack of research on respiratory disease in bioarchaeology, the purpose of this study is to determine whether the hypothesis that poor air quality is positively correlated with the prevalence of chronic maxillary sinusitis and rib periostitis, when factors such as social status are taken into account, can be supported, as has been suggested in previous research (Roberts 2007). This study will also examine some other known causes of chronic maxillary sinusitis and lower respiratory disease, which have been described in the clinical literature, to determine whether there are other causes that can be proven to have an equally strong or stronger relationship with the prevalence of these conditions.

Chronic maxillary sinusitis is defined as the inflammation of the soft tissue in the maxillary sinuses. When this inflammation occurs in a chronic state it can lead to an osteological reaction of the underlying bone of the maxilla (pitting and new bone formation) (Khalid *et al*. 2002; Kocak *et al*. 2002; Schleimer *et al*. 2009). Similarly, when the lungs and/or the pleura are inflamed, this same change can occur on the visceral surface of the ribs (Eyler *et al*. 1996; Guttentag and Salwen 1999). It is not clear how long inflammation must persist before these lesions in the sinuses and on the ribs appear, because direct examination of the sinuses and ribs is unnecessary in the diagnosis or treatment of respiratory conditions in living populations. However, radiographic images demonstrate that these lesions are found in individuals suffering from chronic inflammation of the related soft tissue (Eyler *et al*. 1996; Guttentag and Salwen 1999; Khalid *et al*. 2002; Kocak *et al*. 2002). In the last few decades, it has become increasingly common for these lesions to be recorded in bioarchaeology. However, as there has been so little research into the causes of these lesions in the past, prevalence rates can only be interpreted conservatively. There have been several published papers that have specifically examined and recorded lesions inside the maxillary sinuses and on the visceral surface of the ribs in a small number of populations (Boocock *et al.* 1995; Capasso 2007; Kelley and Micozzi 1984; Lewis *et al.* 1995; Matos and Santos 2006; Merrett and Pfeiffer 2000; Pfeiffer 1991; Roberts *et al.* 1998a; Santos and Roberts 2006). It is this work that has raised awareness of these lesions and resulted in more researchers recording them as part of skeletal analysis. This research has suggested that there is a link between the environmental air quality and prevalence of chronic maxillary sinusitis and rib periostitis. This is further supported by the undeniable link between air quality and respiratory disease recorded in living populations. However, these studies have examined relatively small numbers of populations. Furthermore, not all populations have exhibited the expected prevalence given the estimate or recorded air quality to which the population would have been exposed. It is clear from these anomalous prevalence rates that relationship between air quality and respiratory disease is not as simple as cause and effect.

In order to examine the relationship between these skeletal lesions and the causes of inflammation in the maxillary sinuses or the lower respiratory system, populations from a small geographical region were chosen on the basis of contrasting expected levels of exposure to poor air quality. The populations examined were taken from five English time periods, including, the Iron Age (8^{th} BC- AD 1^{st} C), Roman Period (AD 1^{st} C - AD 5^{th} C), Early Medieval Period (AD 5^{th} C - AD 12^{th} C), Late Medieval Period (AD 12^{th} C - AD 16^{th} C) , and Post Medieval Period (AD 16^{th} C - AD 19^{th} C), in order to explore whether the climate, the environment and the lifestyle associated with these different periods had any effect on prevalence rates. Prevalence rates from urban and rural populations within each of these time periods (where possible) were also compared. Urban populations were defined as having a relatively high population density and a population in which individuals performed more specialised occupations, resulting in repetition of activities. Rural populations were defined by the relatively low population density and a population whose predominant occupation is agriculture. If an individual's primary occupation requires performing a wide variety of activities throughout the day or year, such as in the case of agriculture, they may occasionally perform activities known to be particularly harmful to the respiratory system, such as metalwork or pottery. This will be less deleterious than for a specialist in these fields who is performing the same activities all day every day, assuming this activity affects respiratory health.

In addition to comparing prevalence rates between rural and urban populations, differences in social status were also considered because in previous studies, populations from the same region but different social status groups have had significantly different prevalence rates for chronic maxillary sinusitis. High status populations were defined as being relatively wealthy. By extension, the populations would be expected to live in larger, better built and ventilated houses, be able to afford better fuels, and not participate in occupations that are likely to expose them to high concentrations of air pollution. These populations were defined based on either their method, or location, of burial, as a proxy for wealth, and/or historical documentation regarding the lifestyles of the populations using the burial ground. However, this study also recognises that the identification of social status from the archaeological record is not always straightforward. Low status populations were populations with less wealth who were significantly more likely to work in occupations that regularly exposed them to air pollution. These populations were also more likely to have smaller and less healthy living environments, due to not being able to afford the best locations, properties, technology, or fuels.

1.1.1 Aims

The aim of this study is to explore temporal and environmental trends in the prevalence of chronic maxillary sinusitis and rib periostitis from 12 skeletal samples from Southeast England, dating between the Iron Age (8th C BC- AD 1st C) and the Post Medieval Period (AD 17thC- AD 19th C), representative of populations from urban and rural contexts and high and low social status, where possible. The objective is to determine if the prevalence of chronic maxillary sinusitis and rib periostitis in the samples from Southeast England are correlated with what is known about air quality in the past, based on archaeological evidence. This study had also attempted to examine whether there are alternative causes of respiratory disease in the past, such as those that have been noted in previous clinical and bioarchaeological research (e.g. infection).

1.1.2 Hypothesis

Based on previous research, if respiratory disease in populations in the past is predominantly caused by poor air quality, high prevalence rates are expected in populations with high levels of exposure to pollution in either the indoor or outdoor environment. For the purpose of this study, air pollutants are considered any substances in the air, whether particulates or toxic gases, which may harm respiratory health. The relative air quality is defined by the concentration of pollutants in the air.

1.1.3 Objectives

Primarily this study is interested in confirming whether there is a correlation between air quality experienced by different social status groups or populations living in different environments and the prevalence of chronic maxillary sinusitis or rib periostitis. However, as mentioned above there are many possible causes of these lesions. In addition to the primary objective, this study also sought to answer the following questions.

- Are the lesions associated with chronic maxillary sinusitis and lower respiratory disease related, and if so, can they be attributed to a common cause; in this case, air quality?
- Are there factors other than social status, general environment, and domestic environment that can alter exposure to air quality and therefore influence the results of research into the relationship between air quality and respiratory disease?
- If air quality does not explain the results seen here, is there any evidence suggesting that infection was responsible for the prevalence of both chronic maxillary sinusitis and rib periostitis?
- Was dental disease significantly responsible for the prevalence of chronic maxillary sinusitis in the past? If so, what forms of dental disease may have led to significant numbers of lesions in the maxillary sinuses?

These questions are returned to in the discussion (See Chapter 7).

1.2 Overview of the proceeding chapters

Chapter 2 examines previous research into respiratory disease in the clinical and bioarchaeological literature. As mentioned above, there are a number of known causes of chronic maxillary sinusitis and lower respiratory disease discussed in the clinical literature. In the bioarchaeological literature there appears to be a link between the prevalence of these lesions with a population's exposure to air pollution (Capasso 2000; Lewis *et al.* 1995; Roberts 2007). The focus will be on current theories regarding the causes of respiratory disease in living populations, as well as the causes of lesions in the sinuses and on the visceral surface of the ribs, in both the clinical and archaeological literature in order to understand the exposure of prehistoric and historic populations to poor air quality from southern England. Chapter 3 briefly examines the current understanding of lifestyle and environment from the Iron Age to the Post Medieval Period in relation to domestic, occupational, and atmospheric air pollution. This information was important for selecting the skeletal material to be examined, as well as understanding the resulting data in context. Chapter 4 specifically discusses the skeletal samples used in this study, and provides background information on the samples. Populations were chosen from southeast England due to the continuity use and extent of excavation. The populations were chosen to cover as large a range as was possible under the time restrictions and the availability of skeletal material. This chapter also provides information on the analytical methods used, in addition to the criteria for selecting the samples. Chapter 5 gives the results of the study, including prevalence rates for chronic maxillary sinusitis, with and without visible dental disease, and rib periostitis, the location of these lesions in the skeleton, and whether they were active at the time of death. These data are then discussed in Chapter 6, in relation to data from other bioarchaeological studies, as well as in relation to data from living populations, in order to determine whether one predominant cause of these lesions can be identified. This chapter will also examine each of the possible causes of chronic maxillary sinusitis and rib periostitis and whether they can be confirmed or eliminated based on the data collected in this study. Finally, Chapter 7 summarises the conclusions of this study and suggests future research that could further clarify the causes of respiratory disease in the past

2 Previous Clinical and Bioarchaeological Research on Upper (Maxillary Sinusitis) and Lower (Rib Periostitis) Respiratory Disease

2.1.1 Introduction

More than 1.5 million deaths annually from respiratory infections are attributable to the environment with 20% of cases in developed regions and 42% in developing regions (World Health Organisation 2006). These estimates are conservative as they rely on cases reported in the literature. In developing countries, 36% of lower respiratory infections were attributable to solid fuel use in homes, with only 1% caused by outdoor air pollution. In countries where solid fuels are used domestically, indoor smoke levels are extremely high, with mean attributable fractions (the average difference between the rates of a condition in an exposed population and an unexposed population) often exceeding 40% (World Health Organisation 2006).

In living populations, women and young children generally have the highest levels of exposure because of their time spent in poorly ventilated homes and cooking over open flames. Biomass fuels, any fuel derived from living, or recently living materials, such as wood, and charcoal, are used by more than 3 billion people globally, particularly in the developing world (Akunne *et al*. 2006). These materials burn inefficiently, releasing particulate matter, carbon monoxide, formaldehyde, nitrogen oxides, and poly aromatic hydrocarbons into the environment (Diaz *et al*. 2006). The particulates can penetrate the upper and lower respiratory system, with fine particles reaching as far as the alveoli. Individuals exposed to biomass smoke over long periods of time in poorly ventilated environments often suffer from a condition called "hut lung." This term describes an array of conditions, including chronic obstructive pulmonary disease (COPD), which is a blanket term for irreversible conditions that restrict airflow to the lungs as a results of tissue destruction, inflammation, excess mucus, or loss of elasticity of the lung tissues, such as in the case of bronchitis or emphysema, and other interstitial lung diseases (Diaz *et al*. 2006).

Domestic environments also contain particulate matter as a result of inadequate cleaning of dust, mite, mould and animal dander. The less well ventilated the indoor environment is, the more detrimental the effects can be (Holt 1996). Where these solid fuels are not used, the highest values have been seen in men because of occupational exposure to smoke. The negative effects of this lifestyle have been recorded as lasting for years after the high risk activity is stopped (Diaz *et al*. 2006). Occupations ranging from construction, tanning and textiles, to baking have shown increased risk for respiratory problems (Holt 1996).

Outdoor pollution can also play an important role in the development of respiratory disease. Dockery and co-workers (1996) studied 8,111 adults in six U.S. cities and concluded that individuals exposed to outdoor pollution with fine particulates, including sulphates, were most at risk of respiratory problems after smokers. However, the problems are not limited to polluted urban environments. In areas of intensive agriculture, the environment contains airborne pesticides, particulate matter from manure, and allergens, which cause similar health problems (Takahashi 1976).

In this study, lesions on the bones that make up the maxillary sinuses and the visceral surfaces of the ribs have been recorded as indicators of inflammation of the soft tissues of the maxillary sinuses and lungs respectively. The inflammation of these tissues has several causes. These causes, their origins, and frequency in living populations will be discussed in the following sections so that they may be compared to the prevalence rates recorded for skeletal populations, such that the aetiology of the conditions in past populations can be better understood.

2.1.2 Upper respiratory disease (chronic maxillary sinusitis)

The upper respiratory system is made up of the nose, paranasal sinuses, pharynx, larynx, and the upper trachea. This system prepares approximately 10,000 litres of air inhaled daily, by warming and humidifying it, as well as filtering and neutralizing inhaled particles or pathogens. Particles of at least 12μm are filtered out either by the vibrissae, which are nasal hairs, or by mucus as the air passes through the nasal cavity. The nerves in the nose can also sense irritations, or certain chemicals, and initiate a defensive response, such as sneezing, or producing tears or nasal secretions (Jones 2001).

The respiratory system is lined with pseudostratified ciliated columnar epithelium. Each of these cells contains 200 cilia, which extend into the periciliary fluid, a gel-like layer. The cilia function best at 35-45°C. Above or below these temperatures the beat frequency slows. They are also less functional when relatively dry. However, since the temperature and humidity of the internal environment is usually kept stable by the blood flowing through the capillaries of the nose, which warms and moistens the inhaled air, the cilia are rarely affected by the external environment (Jones 2001). As the ostea are located high on the medial sinus of the wall, when the person is standing upright, it cannot drain by gravity alone. The cilia move a blanket of mucus in co-ordinated waves towards the ostea and into the pharynx where it can be expectorated or swallowed. The mucus' function is to trap and transport inhaled particles so they do not reach the lower airway. It also has immunological properties. Since the lymphatic tissue in the upper respiratory system is limited to the tonsils in the pharynx, the mucus in the nasal and paranasal sinuses contains immunoglobins IgA, IgG, IgM, IgE, enzymes such as lysozomes and lactoferrin, and protective proteins such as neutrophils and lymphocytes, all of which can neutralise harmful microbes (Jones 2001). However, the primary method of eliminating a threat, since it does not directly require the intervention of the immune system, does not lead to the inflammation (Karol 1991; Ramanathan and Lane 2007; Ramanathan and Lane 2007).

The function of the cilia may be affected by chronic respiratory disease. For example, in chronic sinusitis areas of denudement have been found. However, where cilia are found, the beat frequency is normal. Oedema (build up of fluid), shedding of epithelial cells, squamous metaplasia (changes in the epithelial lining caused by irritation), and cilial abnormalities have also been seen in cases of chronic sinusitis (Jones 2001). The abnormal functioning of the cilia hinders the immunological activities and allows micro-organisms to thrive. Under these circumstances inflammation occurs, which, in chronic cases can lead to remodelling of the underlying bone.

The two maxillary sinuses are found lateral to the nasal cavity within the maxilla (see Figure 2.1). Their medial walls are mostly made up of the inferior turbinate, with the uncinate bone superior to it, and the ethmoid behind. Material in the sinus drains into the nasal cavity, into the osteomeatal complex, and aerates through the ostia. In approximately 30% of cases an accessory ostia may be seen (Jones 2001). Suggestion has been made that this anomaly can cause sinusitis, if the mucus which was previous ejected through one ostia by the movement of the cilia, is recirculated back into the sinus through the accessory hole rather than being removed into the nasal cavity (Benninger 2003).

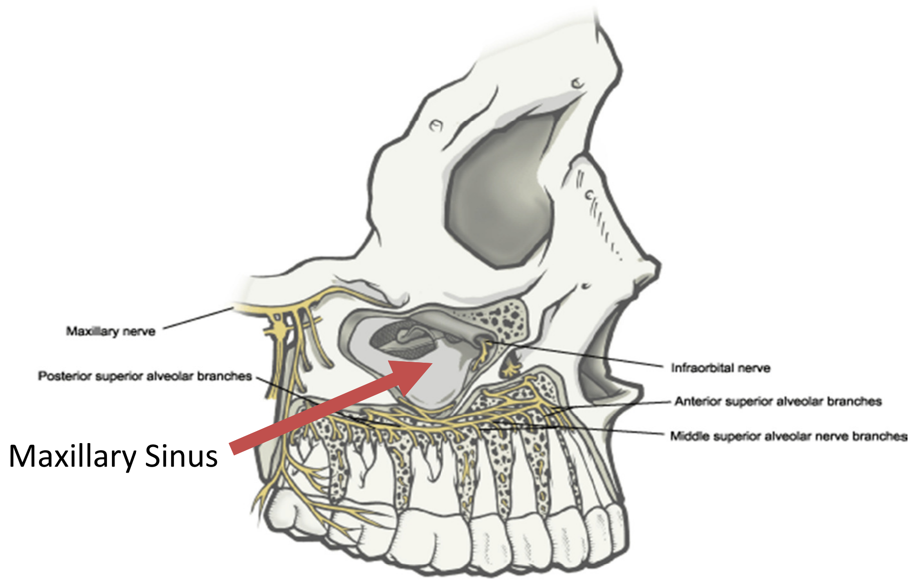


Figure 2.1: Location of the maxillary sinus in the maxilla and in relation to the dentition http://collegeofdiplomates.org/DrLesterQuanDVD200905/ABE%20Part%201%20Written/ABE%20Written%20%20-Reference%20Websites%20-%20January%202008/Local%20Anaesthetic%

There has been a large amount of clinical research into this condition, including its many causes and methods of diagnosis. The causes of sinusitis are not well understood even by clinicians examining living patients and have been the cause of much debate within the clinical literature (Van Cauwenberge *et al*. 2006). Age has been found to be a significant factor in the development of sinusitis. While the overall rate for chronic sinusitis in the United States today is 129 per 1000 persons, it increases significantly with age, from 60 per 1000 persons in individuals under 18, to 140 per 1000 persons for individuals 65 years and older (Bascom and Kesavanathan 1997). Sex has also been found to correlate with the prevalence of sinusitis, whether as a result of biological or cultural differences. A study was completed in the

Department of Maxillofacial Surgery at Kaunas Hospital at the University of Medicine in Lithuania between 1999 and 2004. The results indicated that, of 346 patients (213 females and 133 males) treated for chronic maxillary sinusitis, the mean age in females was 46.6+/-15.0 years and the mean age for males was 42.1+/-14.4 years. This difference was statistically significant (p=0.0024). Females were 1.6 times more likely than males to be diagnosed with chronic maxillary sinusitis during the 5 years this study was conducted (Ugincius *et al*. 2006). Lee *et al* (2004) had similar statistics. The average age of the sample of patients undergoing surgery for sinusitis in Philadelphia between January and July 2003 was 44.3 years old, although more than half had undergone previous surgery for sinusitis.

In addition to age, general health and, perhaps, a genetic predisposition can be a cause of sinusitis. Individuals with overall poor health may physically react to a condition that would provoke no immune response in a healthy individual. Similarly, the immune system of an unhealthy individual may also overreact to a normally minor and easily removed threat, causing a more severe inflammatory reaction than in a healthy individual (Bascom and Kesavanathan 1997) as the inflammation would be more severe, if chronic, it would be more likely to affect the hard tissue. Many articles in the clinical literature describe the various micro-organisms cultured from the mucus of individuals with sinusitis (Alho 2003; Brook 2005; Davis and Kita 2004; Lewis *et al*. 1978; Slavin 2006). However, these same viruses, bacteria, and fungi are also found in control groups not suffering from sinusitis (Steinke and Borish 2004). This calls into question the role of these organisms in the development of sinusitis. As these bacteria are so common even amongst those not diagnosed with sinusitis, it is increasingly suggested that sinusitis is caused not just by the presence of these organisms, but as a result of the individuals more likely having a predisposition to react to these organisms (Kern *et al*. 2008)

As discussed above, the role of the maxillary sinus is to remove and neutralise threats such as micro-organisms. There are several forms that this defence can take. Most often, any potentially dangerous substances are trapped and neutralised within a layer of mucus and evacuated from the sinuses before an immune response is required. If viruses or bacteria are not immediately removed and are allowed to flourish, for example as a result of impairment of the cilia or blockage of the ostia, the local defences are no longer strong enough to neutralise the threat and the immune system must send cells such as dendritic cells, macrophages, and mucosal lymphocytes to the site (Albert *et al*. 2004). The type of response differs depending on the cause, for example the influenza virus would illicit one response while pollutants such as cigarette smoke might produce another (Albert *et al*. 2004). This immune response and the increased blood flow to the area cause an inflammatory response. However, this system can fail. As mentioned above, in some individuals the immune system can be provoked by innocuous substances that would produce no response in other individuals. These responses, unlike acquired responses, which are a result of previous exposure to a substance or pathogen, are innate. These individuals are predisposed, from birth, to give a particular response to certain otherwise innocuous substances that would provoke no response in other individuals (Krouse 2005; Ramanathan and Lane 2007).

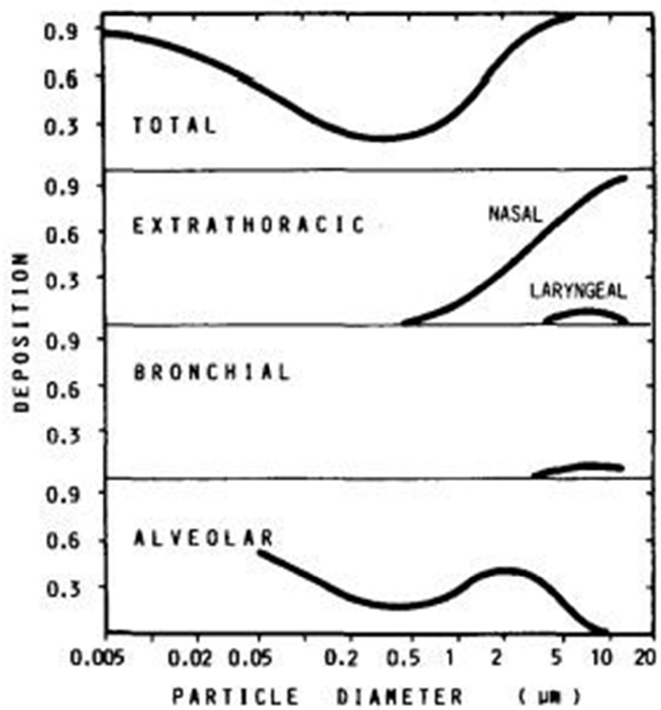


Figure 2.2: : The likelihood of deposition of particulates of varying sizes in different areas of the respiratory system when inhaled nasally at 250 cm3 s- 1 for 8 seconds (Heyder* et al*. 1986)

Other host factors that can affect the prevalence of sinusitis include the morphology of the nostrils and paranasal sinuses. While the concentration of the pollutants in the air (exposure) is important, the amount that actually encounters the tissue in the upper respiratory tract (dose rate) is equally important. The combination of these two factors is referred to as the "delivered dose" (Bascom and Kesavanathan 1997). The delivered dose can be significantly affected by the size and shape of the nostrils. Individuals with round nostrils are known to inhale larger doses of particulates. In addition to increased exposure in the upper respiratory system, this also increases the risk to the lower respiratory system. Individuals with larger rounder nostrils were also found to have up to 30% more particulates reach their lower respiratory system (Bascom and Kesavanathan 1997). Based on this study, if nostril size is significantly contributing to the prevalence of chronic maxillary sinusitis in the past, it would be reasonable to expect a correlation between this and the prevalence of rib periostitis, assuming that inhaling the increased concentrations of particulates into the lungs leads to chronic inflammation there as well.

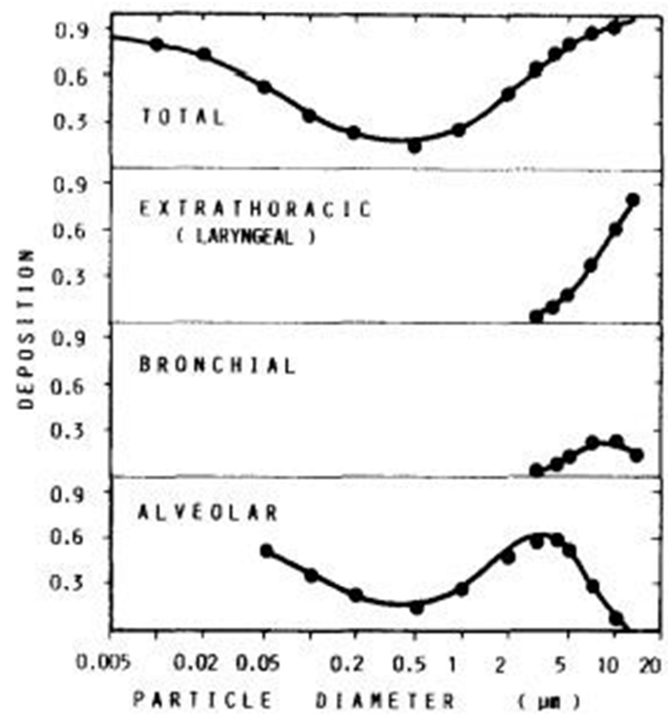


Figure 2.3: The likelihood of deposition of particulates of varying sizes in different areas of the respiratory system when inhaled orally at 250 cm3 s- 1 for 8 seconds (Heyder* et al*. 1986)

It is not just the morphology of the upper respiratory system that can affect how much pollution is inhaled. The rate of breathing and the unique shape of each particulate combined with the unique structure of each individual's respiratory system can have an effect as well (Heyder *et al*. 1986; Kim and Hu 1998; Löndahl *et al*. 2008). Particulates of 10µm or less are likely to be inhaled into the lungs. Particles larger than this, but too small to be filtered out by nasal hair (<12 µm), can penetrate the maxillary sinuses (Heyder *et al*. 1986; Jones 2001; Kim and Hu 1998; Lebowitz 1996). Once it enters the maxillary sinus, if it is not ejected it may lead to inflammation. However, whether the particulates are inhaled through the mouth or nose, the rate of breathing, and many other factors affect whether particulates reach the lungs as well as how deeply they penetrate (Heyder *et al*. 1986; Kim and Hu 1998) (see Figures 2.2 and 2.3).

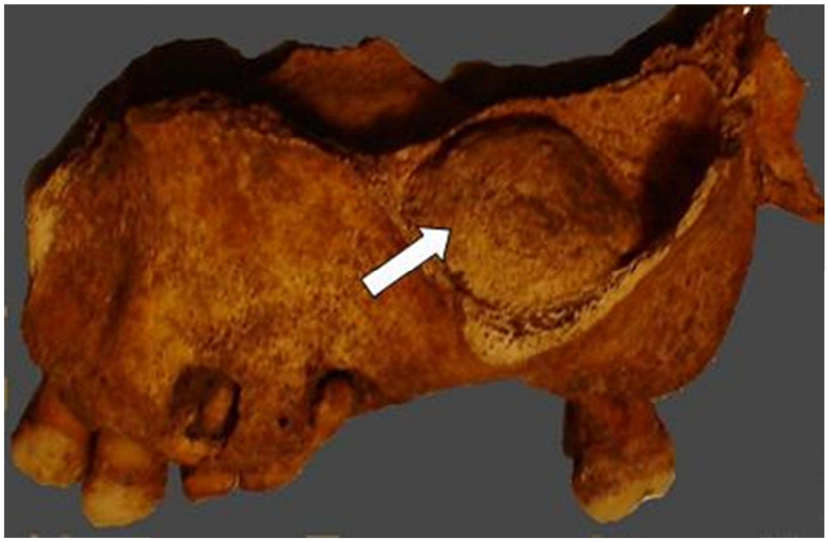


Figure 2.4: Benign tumour on the floor of the left maxillary sinus in an individual from Bishopsmill School, Norton, decreasing the overall space in the sinus

The maxillary sinuses are the first air sinuses to form, at four months gestation. While the timing differs from person to person and even between the two individual sinuses, the sinuses are essentially fully formed around the ages of twelve to fourteen, when the permanent dentition are fully erupted (Brook 2006). However, studies have found the maxillary sinuses may continue to increase in size in females until their twenties, and in males, until their 30's (Jun *et al*. 2005). Beyond this age, the volume of the sinuses typically decreases (Jun *et al*. 2005). The size of the maxillary sinuses also changes throughout life because of pathology. The sinuses more often decrease in volume than enlarge. Enlargement is typically caused by air or mucus becoming trapped in the sinuses. Reduction can be caused by developmental problems, congenital conditions, systemic disorders which cause expansion of the bone of the maxilla, such as hypothyroidism or sickle cell anaemia, trauma, cysts, and most commonly, neoplastic disorders, such as tumours, which reduce the space in the sinus, (Lawson *et al*. 2008) (see Figure 2.4).

There are many non-host factors, which can increase the prevalence of chronic maxillary sinusitis. As mentioned above, the concentration of pollutants in the atmosphere is commonly cited in bioarchaeological studies of sinusitis (Lewis *et al.* 1995; Merrett 2004; Merrett and Pfeiffer 2000; Roberts 2007). Many clinical studies have found significantly higher levels of sinusitis in individuals exposed to high concentrations of atmospheric pollution (Ait-Khaled *et al.* 2001; Akunne *et al.* 2006; Bailie *et al.* 1999; Balakrishnan *et al.* 2002; Benneh *et al.* 1993; Boleji *et al.* 1989; Boman *et al.* 2006; Brauer *et al.* 1996; Chen *et al.* 1990; Cleary and Blackburn 1968; Davidson *et al.* 1986; Diaz *et al.* 2006; Dockery *et al.* 1996; Ellegard 1997; Ezzati and Kammen 2002; Institute 1995; Norboo *et al.* 1991; Parikh *et al.* 2001; Perez-Padilla *et al.* 1996; Riojas-Rodriguez *et al.* 2001; Santos-Burgoa *et al.* 1998; Sanyal and Maduna 2000; Smith *et al.* 1983; Smith *et al.* 2004; Trevino 1996; Venners *et al.* 2001). Many of these cases are discussed in the introduction to this chapter. According to the World Health Organisation, air quality inside buildings, whether the home or at work, has the largest effect on respiratory health, while the external atmosphere accounts for only one percent of the cases of respiratory disease (World Health Organisation 2006). Individuals who spend the most time indoors within this poor air quality are most likely to experience respiratory conditions as a result. As many of these studies are conducted in developing countries it is most frequently the women and children who spend the most time in proximity to fires which burn poor sources of fuel and lead to the poorest air quality in the home (World Health Organisation 2006). Outside of the developing world where these forms of fuel are not used as frequently in the home, it has been shown that individuals in large population centres, exposed to poor air quality due to car exhaust and industrial pollution are most likely to experience respiratory conditions (Dockery *et al*. 1996). Sih (1999) attempted to determine whether there was a correlation between urban air pollution and respiratory health in living populations. Studying a total sample of 2,000 children between 7 and 14 years old from Sao Paolo State Public School in Sao Paolo, Brazil, between November 1996 and February 1997, she found a rate of 12% for various respiratory complaints, including sinusitis, in the 1,000 children from the City of Sao Paolo, and 8% in the 1,000 children from the less polluted rural area around Tupa. These results strongly correlated environment with respiratory health in general in this situation.

A similar study was carried out in Japan between 1952 and 1955, which found that the incidence of chronic maxillary sinusitis was more than six times higher among the rural children compared to the urban children. However, when the study was repeated by Takahashi (1976) between 1972 and 1975, the results had changed significantly, with 19.2% of the urban children suffering chronic maxillary sinusitis, compared to 8.9% of the rural children. This difference has been attributed to the economic and industrial growth in the intervening period, which caused a rise in urban air pollution. In the absence of high levels of pollutants in the urban environment, the pollutants caused by intensive agriculture and domestic activities made rural populations more prone to respiratory infection than the nearby urban populations.

In addition to atmospheric pollution, other environmental factors play an important role in the development of the condition. Koskinen and colleagues (1999) examined individuals in 310 Finnish homes built over the 20th century. They found that the 11% of people living in houses considered to have high concentrations of moisture had been diagnosed with sinusitis as opposed to only 8% in houses without high levels of moisture (odds ratio 1.92 in adults).

Clinical research has found that dental disease is responsible for a significant percentage of individuals affected by sinusitis. Meln and colleagues (1986) found that of 198 patients with sinusitis, observed over 5 years, 40.6% of the cases were of dental origin. However, according to Mehra and Jeong (2009), the incidence of odontogenic chronic maxillary sinusitis is very low, approximately 10-12% of cases of chronic maxillary sinusitis. Given that the bone that makes up the floor of the sinus is much thicker than the bone making up the lateral maxilla surrounding the tooth roots, infection is much more likely to penetrate laterally than anteriorly into the sinus. However, the maxillary molars sit directly below the lateral wall of the maxillary sinus; the closest, the second molar (M2), on average, lies just 1.97mm below the sinus floor. The premolars are slightly further, with the buccal root of the first premolar lying on average 7.5mm from the sinus floor (Brook 2006). In some cases, the floor of the sinus can descend with time and the tip of the tooth roots can protrude into the maxillary sinus with only a thin layer of bone covering them. This increases the risk of dental infection spreading into the sinus if that tooth is affected by severe dental disease (Brook 2006). The facial muscles, which connect to the lateral wall of the maxilla, tend to direct maxillary dental disease from the dentition up to the lateral wall. As the bone of the lateral wall is not as dense as the sinus floor, this makes it easier to penetrate and as a result, more susceptible to infection

(Brook 2006). The incisors and canines have little or no contact with the floor of the sinus, and it is less likely that dental disease in these teeth will affect the sinus.

While clinical studies of sinusitis typically focus on the effects on the soft tissue, as it is more commonly (and in acute cases, solely) affected, more researchers have begun to examine the bone reaction in the sinus. With the previous focus on treating soft tissue, research was necessary to find explanations for cases that persisted in spite of treatment. They have found that the symptoms were returning in individuals where the bone had been affected but not treated (Chiu 2005; Lee *et al*. 2004). As a result, clinical studies have recorded remodelling of the bone surrounding the sinus, particularly in computed tomography (CT) images, which are commonly taken where endoscopic surgery is used in treatment. They have found that remodelling does typically occur in response to chronic inflammation (Cho *et al.* 2007). The severity of the bone remodelling has also been found to be positively correlated with the severity of the soft tissue inflammation (Giacchi *et al.* 2001).

Giacchi *et al* (2001) endoscopically examined the ethmoid bone in 19 patients undergoing endoscopic sinus surgery for chronic sinusitis. Eighteen (95%) had evidence of bone resorption and remodelling. This was compared to a control group of five patients who had no evidence or history of sinusitis that had CT images taken before undergoing surgery for a cerebro-spinal fluid leak. Of these, three (60%) had bone changes in their sinuses, but all cases were less severe than the group diagnosed with sinusitis. This emphasises that some individuals who are asymptomatic, or are not so symptomatic as to feel the need to seek medical attention, may also show evidence of remodelling in the maxillary sinuses. Tovi *et al*. (1992) examined osteoblastic osteitis, a rare infection defined by severe periosteal bone formation caused by chronic or recurrent sinusitis, in four individuals with sinusitis. Even severe bone reaction of this type, produce just vague facial discomfort, and could only be diagnosed by radiographs (Tovi *et al*. 1992).

In addition to studies of human maxillary sinuses, some studies have used animal models to determine the effects of infection and soft tissue inflammation on the underlying bone. While, the traditional belief is that inflammation of the soft tissue irritates the bone tissue, Kahlid and colleagues (2002) and Perloff and co-workers (2000) both examined the underlying bone from maxillae of New Zealand white rabbits after injecting bacteria into only one sinus. After sacrificing the rabbits they examined the non-injected sinus and found that, even though there were no soft tissue changes, the bone had remodelled in 52% of cases after 6-9 weeks of infection (Khalid *et al*. 2002) and 100% of cases after 13 weeks (Perloff *et al.* 2000). In all cases, there were also enlarged Haversian canals, which led the researchers to suggest the bacteria were using the canals to travel from the infected sinus to other areas of the maxilla.

2.1.3 Lower respiratory disease (rib periostitis)

The lower respiratory system is primarily located in the chest cavity. Air is inhaled through the bronchi, bronchioles and finally into the alveoli, where the gases are exchanged between the lungs and the vascular system. Breathing takes place when the muscles of the chest expand the chest cavity by pulling the ribs. The chest cavity is lined internally with two extremely thin layers of tissue, each one cell thick, together referred to as the pleura. The outermost (parietal pleura) lies against the visceral surface of the ribs while the innermost layer (visceral layer) covers the lungs and other cardiovascular structures in the pleural cavity (see Figure 2.5). This tissue, which comes into contact with all of the ribs to some extent, maintains a negative pressure in the chest cavity, so that when the chest muscles contract, the space surrounding the lungs increases, causing the lungs to expand as well (Albert *et al*. 2004).

Between the two layers of the pleura is a minute amount of serous fluid which is constantly produced by the pleura and reabsorbed by the lymphatic system. The small amount of fluid constantly present in the pleural cavity allows the two layers to move in relation to each other. It is possible for fluid to accumulate in the pleural cavity, which is referred to as pleural effusion. It is also possible for microbes from the blood stream to reach the pleural fluid and cause inflammation (pleuritis) (Albert *et al* 2004). In addition to the pleura itself, the lungs can become inflamed due to infections such as tuberculosis, bronchitis, brucellosis, pneumonia, mycoses, cyptococcosis, nocardiosis, histoplasmosis, blastomycosis, and actinomycosis, (Albert *et al*. 2004; Molto 1990). Chronic inflammation of the lungs or pleura can cause the visceral surface of the ribs to remodel, which has been confirmed by radiographs (Eyler *et al*. 1996; Guttentag and Salwen 1999).

In a modern clinical setting, an observation of rib periostitis is not necessary for making diagnoses of specific respiratory diseases. Therefore, there is very little data available on frequency in living populations of the types of lesions that are associated with inflammation seen in skeletal samples. Attempts have been made to connect rib periostitis to respiratory disease in living patients. Eyler *et al* (1996), using radiographs, found that rib enlargement and rib periostitis was commonly associated with severe chronic pleural inflammation. Guttentag and Salwen (1999) noted new bone formation on the visceral surface of the ribs of individuals suffering from the early stages of respiratory infection.

In the early stages of respiratory disease it is possible that very little remodelling may have occurred and therefore it would not be seen using radiography. It is likely that if an individual has radiographs taken, they would receive treatment for respiratory conditions, and the lesions would not progress to more severe forms. Since in palaeopathology the ribs are examined macroscopically, this could lead to a discrepancy between modern data and archaeological data. Very small amounts of remodelling would be visible on the ribs, and medical treatment would not have been an option throughout much of history, possibly resulting in more severe manifestations of conditions. Also, clinical records would likely only include individuals who sought medical treatment. The skeletal populations used in this and other bioarchaeological studies would include all individuals preserved within a burial population regardless of whether they were symptomatic.

The most accurate comparison would be if the archaeological prevalence rates were compared with those collected by observing the ribs from post mortem examinations, however the surfaces of ribs are not checked for lesions during autopsy procedures and therefore no data has been compiled (Matos and Santos 2006). Several studies have used historical burial populations for which there are relatively complete records (Kelley and Micozzi 1984; Matos and Santos 2006; Roberts *et al*. 1994; Santos and Roberts 2006). However, the focus of these studies has typically been on the relationship of these lesions to tuberculosis. This will be discussed further in the section 2.2 below.

Biomass fuels and inefficient stoves used in poorly ventilated environments have been associated with a number of conditions including COPD, acute respiratory infections, low birth weight, increased infant and perinatal mortality, pulmonary tuberculosis, nasopharyngeal and laryngeal cancers, cataracts, and lung cancer (Bruce *et al*. 2000). Environment is believed to be responsible to at least 42% of cases of lower respiratory disease in the developing word while only 20% in the developed world (World Health Organisation 2006). Respiratory disease has been particularly prevalent in women and young children who spend the most time in the home and cooking close to the fire in the living populations that use these technologies (Bruce *et al*. 1998; Chen *et al*. 1990; Riojas-Rodriguez *et al*. 2001). Wong and colleagues (2004) found that of 426 children from two private residential estates in Hong Kong in 1994, 111 (26.1%) children reported at least one respiratory illness, either allergic rhinitis, asthma, bronchitis, sinusitis, or pneumonia. Of these children who lived in households that cooked with gas stoves one, two and three times daily, 21 (18.9%), 41 (36.9%), and 49 (44.1%), respectively, reported respiratory problems. Ekici (2005) found that of 596 women less than 40 years old, living in 10 villages situated around Kirikkale, Turkey, an area free of industrial pollution, women exposed to biomass fuel in the home were 2.5 times more likely to suffer from obstructive airway disease. Twenty-three percent of the cases of respiratory disease could be attributed to the exposure to biomass smoke.

2.1.4 Summary

It is clear from the previous sections that there is much debate within the medical community concerning the causes of sinusitis. All of the many factors that have been proven in the clinical literature to cause inflammation within the sinuses need to be considered as possible causes in any given archaeological individual's remains. However, some causes are more frequent than others, and are statistically more likely to be the cause in any given individual. Conversely, there is very little clinical literature that discusses the effects of inflammation of the lower respiratory system on the visceral surface of the ribs. As this has no effect on understanding the causes, making the diagnosis, or deciding on treatment of these conditions this lack of research is understandable. Both of these cases present their own problems in understanding these lesions in skeletal populations.

Furthermore, the prevalence rates given in the clinical literature depend on individuals seeking medical attention, or being included in research studies, such as surveys, where results are reported directly or indirectly in the literature. Whether people seek medical attention and how they describe their symptoms when questioned in studies depends on the severity of symptoms, personality, ability to cope with the symptoms, ease of access to medical help, and many other factors. By comparison, archaeological studies examine cemetery population for any individuals with bone remodelling who are excavated and sufficiently preserved. In this case the rates may still be altered depending on why individuals were buried in a particular place.

In addition to these problems, when discussing environment, many of these factors differ significantly for individuals that died over one hundred years ago and populations that lived within the last twenty years. There are many more atmospheric and domestic pollutants modern living populations are exposed to that even populations from the industrial revolution would not have been. As a result of many of these factors, it is difficult to directly compare clinical prevalence rates with archaeological rates. However, it would be expected that the patterns of higher rates in environments with poorer air quality, as well as differences related to gender roles and activities would still exist. Clarifying this understanding of the causes of sinusitis and rib periostitis in archaeological populations will be the focus of the remainder of this dissertation.

2.2 Respiratory Disease in Bioarchaeology

2.2.1 Introduction

There is much less research into respiratory conditions in the archaeological literature than in the clinical literature. This is not difficult to understand as the respiratory system is almost exclusively composed of soft tissue. As this soft tissue very rarely survives to be examined more than a hundred years after burial this makes the respiratory system difficult to examine. As mentioned above, given that bone remodelling is an indirect result of inflammation, the exact causes are difficult to ascertain. In addition, as discussed in the previous section, the causes of sinusitis are not well understood even among the clinicians. In spite of this, there have been some studies that have examined sinusitis, many of which have concluded that there is a link between these bone lesions and poor air quality, however these are small studies. By comparison, very few researchers have looked at rib periostitis. Those who have are primarily interested in their relationship to tuberculosis. However, without larger, wider scale studies, is it possible to accept air quality as the most likely aetiology? The following sections will discuss this previous bioarchaeological research and its contribution to this study.

Comparing the prevalence rates calculated by so many different researchers in so many different contexts particularly for conditions which are not regularly recorded can be complicated. Both sinusitis and rib periostitis, like any other bone lesions can fall within the range of severity anywhere from minor to severe. Minor cases may be easily overlooked if the researcher is not specifically looking for them, or the bones have not been completely cleaned. In many cases, due to their position within the maxilla, the maxillary sinuses may not be cleaned out at all. In addition to this, where the maxilla is not so significantly damaged that the sinuses can be viewed macroscopically, if an endoscope is not used to view the sinus, it will not be included in the prevalence rate. Under these circumstances, it is possible, as in any study, that there is some inter-observer error. Also problematic are the differences in the recording methods. While some studies provide true prevalence rates, where the number of affected elements is compared against the number of that element preserved, other studies record the prevalence using crude prevalence rates, where the number of affected elements is compared against the total number of individuals in the population. This, and its effect on the comparison of results, will be discussed further in the remaining chapters.

2.2.2 Chronic maxillary sinusitis

As most of the sites that have been used to put the twelve samples in this study into context were analysed by different researchers, it is possible that there were differences in the definition of sinusitis. For example, in this study any remodelling, regardless of how small, and regardless of the location within the sinus, sinusitis was regarded as present. In addition, the endoscope was used in any cases where the sinus could not be observed macroscopically. This is rarely the case in the prevalence rates discussed in the remainder of this section. This is in part due to the fact that there are no accepted standards for recording these lesions.

Given in Figure 2.5 are prevalence rates from several sites whose studies focused on sinusitis and gave their results as true prevalence rates, both in the United Kingdom and internationally. The prevalence rates are calculated as the number of individuals with sinusitis in one or both sinuses of the number of individuals with one or both sinuses preserved. Other data which are given in the following sections were not included in Figure 2.5, as the data were presented as crude prevalence rates.

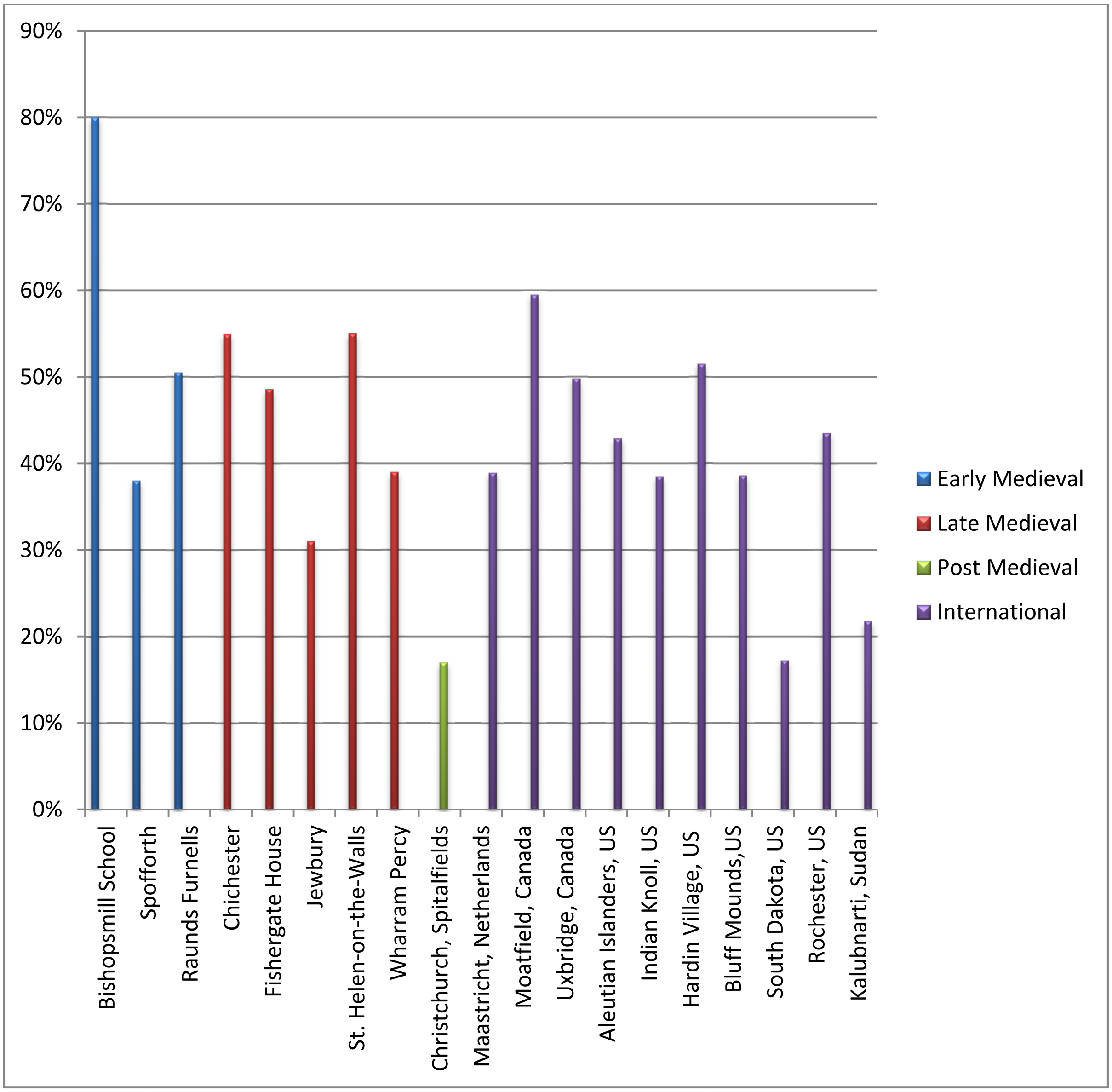


Figure 2.5: Prevalence of chronic maxillary sinusitis in 19 previously recorded sites. The percentage is calculated as the number of individuals with sinusitis in at least one sinus of the total number of individuals with one or both sinuses preserved.

2.2.2.1 Chronic maxillary sinusitis in England

England	Location	Dates	Description	N	N	%	Reference
Bishopsmill School	County Durham	AD 900-1200	Agricultural/Rural	25	20	80%	Bernofsky 2006
Spofforth	Yorkshire	AD 700-1200	Agricultural/Rural	35	15	42.9%	Bernofsky 2006
Raunds Furnells	Northamptonshire	AD 700-900	Agricultural/Rural	109	55	50%	Roberts *et al* 1995
Chichester	Sussex	AD 1100-1500	Agricultural/Urban Leprosy Hospital	133	73	54.9%	Boocock *et al* 1995
Wharram Percy	Yorkshire	AD 900-1800	Agricultural/Rural	169	86	39.55%	Lewis *et al* 1995
St. Helen-on-the-Walls	Yorkshire	AD 1100-1500	Agricultural/Urban Low Status	114	82	54.69%	Lewis *et al* 1995
Fishergate House	Yorkshire	AD 1100-1500	Agricultural/Rural Low Status	109	53	48%	Roberts 2007
Christ Church, Spitalfields	London	AD 1700-1800	Urban Middle Class	417	71	17%	Roberts 2007

Table 2.1: English skeletal populations that have previously been analysed. N= the number of individuals with at least one sinus more than 10% preserved; n= the number of individuals with sinusitis in at least one sinus.

The prevalence of sinusitis has been calculated for a number of skeletal collections from England. The way these prevalence rates are calculated and the methods used to locate and define sinusitis, however are not always consistent. Given above in Table 2.1, is a list of eight sites that have previously been analysed from England whose methods and data are presented in such a way that they are comparable to the data in this study. As these sites do not encompass the entire time period being analysed in this study, in order to put the sites from these periods into context, prevalence rate for sites which could not be included in this table and where necessary, general numbers for an entire period are given in the proceeding sections. These prevalence rates were recorded under varying circumstances, in many cases as part of larger studies and reports.

2.2.2.1.1 Prehistoric Period

The Prehistoric Period in England extends from the Palaeolithic in 10,500 BC to the end of the Iron Age in AD 100. The Iron Age, which is the period analysed in this study, is defined as the period from the 8^{th} C BC to the AD 1^{st} C.

There have been few skeletal samples from these periods analysed for chronic maxillary sinusitis. The first case of sinusitis in Britain is found in one individual from the Neolithic Period at Wayland's Smithy (Brothwell and Cullen 1991). Wells (1977) found no cases of sinusitis in nine Iron Age individuals and 19 Bronze Age individuals; however these sample sizes are too small to support the conclusion that there was no sinusitis. Roberts and Cox (2003) describe two cases of chronic maxillary sinusitis found in the Bronze Age and one case of sinusitis at Beckford, Hereford, which spans the Late Iron Age and early Roman Period. These low prevalence rates were thought to signify relatively healthy living conditions in houses that had relatively good ventilation. However, as will be seen in section 3.2.1., there is no evidence that this is the case. It is more likely that these low prevalence rates represent a low rate of recording rather than actual prevalence rates.

2.2.2.1.2 Roman Period

In the Roman Period, which in England extended from the early AD second century to the early AD fifth century, Wells (1977) found two (2.8%) cases of chronic maxillary sinusitis in 72 individuals with intact sinuses, an increase over the earlier periods. Roberts and Cox (2003) list nine sites for which they found prevalence rates for sinusitis, however due to the inconsistency of the method of reporting, the only way to make these sites comparable was to present them as crude prevalence rates. These prevalence rates are given in Table 2.2. The increase in the prevalence from the prehistoric period may reflect the temperature decline, an increase in indoor pollution, or may reflect the changing lifestyle. Most of the skeletal populations analysed from this period are recovered from cemeteries associated with towns.

The increased population density and human contact could have increased the rate of infectious disease and be responsible for an increase in the prevalence of sinusitis, if this is an accurate picture of what was happening.

England	Location	N	n	%	Reference
Baldock 1	Hertfordshire	190	5	2.6	McKinley 1993
Baldock 3	Hertfordshire	145	1	0.7	Roberts 1984
Barrows Hills, Radley	Oxfordshire	57	1	1.7	Harman no date: In Roberts and Cox 2003
Boscombe Sports Field, Boscombe Down	Wiltshire	37	3	8.1	McKinley 1996
Cirencester South	Gloucestershire	362	7	1.9	Wells 1982
Colchester	Essex	575	10	1.7	Pinter- Bellows 1993
Eastern Cemetery	London	550	5	0.9	Conheeny 2000
Owslebury	Hampshire	49	2	4.1	Wells and Collis: In Roberts and Cox 2003
Tolpuddle Hall	Dorset	48	2	4.2	McKinley 1998
Total		2013	36	1.79	

Table 2.2: The crude prevalence rates of sinusitis from the Roman Period, copied from Roberts and Cox 2003.

2.2.2.1.3 Early Medieval Period

England	Location	N	N	%	Reference
True Prevalence					
Bishopsmill School	County Durham	25	20	80	Bernofsky 2006
Spofforth	Yorkshire	35	15	42.9	Bernofsky 2006
Raunds Furnells	Northamptonshire	109	55	50	Roberts *et al* 1995
Crude Prevalence					
Beckford B	Herefordshire	108	1	0.9	Wells 1996
Butler's Field, Lechlade	Gloucestershire	221	3	1.3	Harman and Jones 1998
Caister on Sea	Norfolk	139	2	0.1	Anderson 1993
Eccles	Manchester	166	3	1.8	Boocock *et al* 1995
North Elmham Park	Norfolk	206	1	0.5	Wells and Cayton, 1980
Porchester Castle	Hampshire	11	1	9	Hooper 1976
Portway, Andover	Hampshire	68	5	7.3	Henderson and Wells 1985
Red Castle, Thetford	Norfolk	85	1	1.2	Wells 1967
South Acre	Norfolk	119	2	1.7	McKinley 1996
Staunch Meadow, Brandon	Suffolk	158	2	1.3	Anderson 1990
Tanner's Row, Pontefract	Yorkshire	178	6	3.4	Lee: In Roberts and Cox 2003

Worthy Park, Kingsworthy	Hampshire	101	6	5.9	Chadwick Hawkes and Wells 1983
York Minster	Yorkshire	60	4	6.7	Lee: In Roberts and Cox 2003
Total		1620	37	2.28	

Table 2.3 : The true prevalence rate of populations examined from the Early Medieval Period, where available, and the crude prevalence rates of Early Medieval Populations copied from Roberts and Cox 2003.

Based on the previous research, the prevalence of chronic maxillary sinusitis rises substantially in the Early Medieval Period, which, in England, began in the early fifth century AD and ended in the mid eleventh century AD. This period had the highest frequency in Wells' (1977) study with 14 (6.8%) cases of sinusitis in 204 individuals from a pooled sample from fifteen sites. He suggests that the populations in this period would have been exposed to increased levels of domestic pollution from central hearths. The housing would have been similar to that of earlier periods; however, Wells suggests that they were less well ventilated than the Prehistoric period and unlike the Roman Period, cooking would have been carried out indoors, exposing the inhabitants to increased concentrations of smoke over longer periods of time. However, as is seen in section 3.2.3, it is unlikely that this is the case. Furthermore, when examining the crude prevalence rates from the previous period (See Table 2.2) to the crude prevalence rates from this period (See Table 2.3), the overall prevalence rate is only marginally higher and not significantly so (χ^2= 0.882, p=0.3476).

However, it is not clear how accurate the crude prevalence rates given in table 2.3 are. The true prevalence rates given at the top of the table are all considerably higher. In all three populations for which true prevalence rates are available maxillary sinusitis was a focus of the research and therefore may have gotten more attention than it would have as part of a general assessment of skeletal material. It is possible that, in some of the populations where only one or two individuals were recorded as having sinusitis, this condition was only recorded because a particularly significantly case was encountered and noted. If that was the case, the more minor manifestations would have gone unrecorded, lowering the prevalence.

2.2.2.1.4 Late Medieval Period

The Late Medieval period extends from AD 11th C to AD 16th C. Wells (1977) found three cases of sinusitis in a sample of 83 individuals from this period. However, subsequent studies have found higher prevalence rates, particularly in poor urban populations. At Wharram Percy, a rural site from Yorkshire (12th-16th C), Lewis *et al* (1995) found that of 268 individuals with sinuses 106 (39.5%) had chronic maxillary sinusitis while at St. Helen-on-the-Walls, a poor urban parish cemetery from York (10th- 19th C), 134 (54.7%) of 245 individuals with sinuses, had chronic maxillary sinusitis (Lewis *et al.* 1995). However, this prevalence rate included children, who are not included in this current study. When these individuals aged below 17 are removed at Wharram Percy 91 (51.4%) of 177 adults had sinusitis and at St. Helen on the Walls 119 (63.3%) of 188 adults with sinuses preserved had sinuses. This is similar to the result from the population from the cemetery of Fishergate House, in York (12th and 16th C), also a lower status population living in the same city at roughly the same time. They had evidence of sinusitis in 53 (48.6%) of 109 individuals with at least one sinus (Papapelekanos 2003).

As a contrast, also in Late Medieval York, the cemetery site of Jewbury had 28 (31%) of 90 individuals with chronic maxillary sinusitis (Lilley *et al.* 1994). According to Roberts (2008) this population would have been higher status than the two late medieval populations from York, discussed above. This relatively low prevalence rate compared to the other two York populations could be attributed to the difference in status. If the conditions this population lived in were less crowded and exposed the population to less smoke, this could account for the difference in sinusitis. At a Late Medieval leprosy hospital in Chichester, England (12th-16th C), Boocock *et al* (1995) found 73 of 133 individuals (54.9%) had chronic maxillary sinusitis. While this site is categorized as urban, as a leprosy hospital it would have been removed from the unhealthy urban environment and the inhabitants would not have carried out the same activities as the normal population in daily life.

2.2.2.1.5 Post Medieval Period

There have been very few Post Medieval skeletal samples that have been assessed for chronic maxillary sinusitis. In England, the Post Medieval Period is defined as the sixteenth century AD to the middle of the nineteenth century AD. At Christ Church, Spitalfields in London 71 (17.7%) of 418 individuals with at least one preserved sinus displayed bone remodelling associated with chronic maxillary sinusitis (Roberts 2007). Based on the previous research it appears that the prevalence of chronic maxillary sinusitis suddenly declines in this period, which is counter-intuitive. The cemetery populations that have been excavated and been dated to the Post Medieval Period are predominantly urban, and, for the most part were living in poorly ventilated stone houses, in polluted environments, in close proximity to neighbours and industrial centres (Brimblecombe 1987). If these factors are the most influential, it would be expected that the highest rates would be seen here, however they are not. This could be due to the osteological paradox (Wood *et al.* 1992). It is possible that the low rate in this population relates to social status. The population from Christ Church, Spitalfields was middle class, and may have been at lower risk of developing these conditions since their homes would been larger and better ventilated and they would not have taken part in high risk occupations, such as tanning and mining (Roberts 2007). Conversely, if low rates were found in poorer populations with lower age at death, overall poor health or acute disease, including respiratory disease, may have killed them before the condition affected the bone (Wood *et al.* 1992).

2.2.2.2 Respiratory Disease Outside of England

2.2.2.2.1 Europe

Searching several databases of predominantly English-language journals, there was only one prevalence rate for a European site, which had been published. This site, Maastricht, published by Panhuysen *et al* (1997), located in the Netherlands was made up of three skeletal populations, shown below (see Table 2.4). The first population, Boschtraat, was a small rural settlement of 54 individuals with modest graves. Servaas, from an "urban" site consisted of 282 middle-class to elite burials, however the population density would have been low and the environmental conditions would have been more similar to rural populations. The last site is a former convent from Maastricht, consisting of 99 middle to high status individuals. Prevalence rates were not given for the individual groups. Pooling all three sites, there were 49 (38.9%) individuals with chronic maxillary sinusitis. This result is similar to Medieval rural sites in Britain. These prevalence rates are given in Table 2.4.

Europe	Location	Dates	Description	N	N	%	Reference
Boschstraat	Maastricht, Netherlands	AD 600-800	Agricultural/Rural Low Status				Panhuysen 1997
Servaas	Maastricht, Netherlands	AD 450-950	Agricultural/Rural Middle Class-Elite				Panhuysen 1997
"Nunnery"	Maastricht, Netherlands	AD 1250-1600	Agricultural/Rural Middle-High Class				Panhuysen 1997
Maastricht Pooled				126	49	38.9%	

Table 2.4: Prevalence of chronic maxillary sinusitis at Maastrict, Netherlands.

2.2.2.2.2 North America

North America	Location	Dates	Description	N	n	%	Reference
Moatfield Ossuary	Ontario, Canada	AD 1300	Agricultural/Rural	74	44	59.5%	Merrett 2004
Uxbridge Ossuary	Ontario, Canada	AD 1410-1483	Agricultural/Rural	207	103	49.8%	Merrett and Pfeiffer 2000
Aleutian Islanders	Alaska, USA	AD 1500-1600	Hunter-Gatherer/Rural	35	15	42.9%	Roberts 2007
Indian Knoll	Kentucky, USA	4570-3500 BP	Hunter-Gatherer/Rural	96	37	38.5%	Roberts 2007
Hardin Village	Kentucky, USA	AD 1550-1675	Agricultural/Rural	33	17	51.5%	Roberts 2007

Bluff Mounds	Illinois, USA	AD 800-1100	Hunter-Gatherer early agriculture/ Rural	70	27	38.6%	Roberts 2007
South Dakota	South Dakota, USA	AD 1500-1800	Seasonal Hunter-Gathering/Rural	87	15	17.2%	Roberts 2007
Rochester	New York, USA	AD 1826-1855	Urban, Poorhouse	60	26	43.5%	Lew and Sirianni 1997

Table 2.5: The true prevalence rates available for populations from various times in North America.

There have been several skeletal populations from North America for which prevalence rates for sinusitis have been calculated. Given above in Table 2.5 are some examples of sites that were calculated in such a way that they are comparable to the data in this study. These prevalence rates are also shown graphically in relation to economy in Figure 2.6.

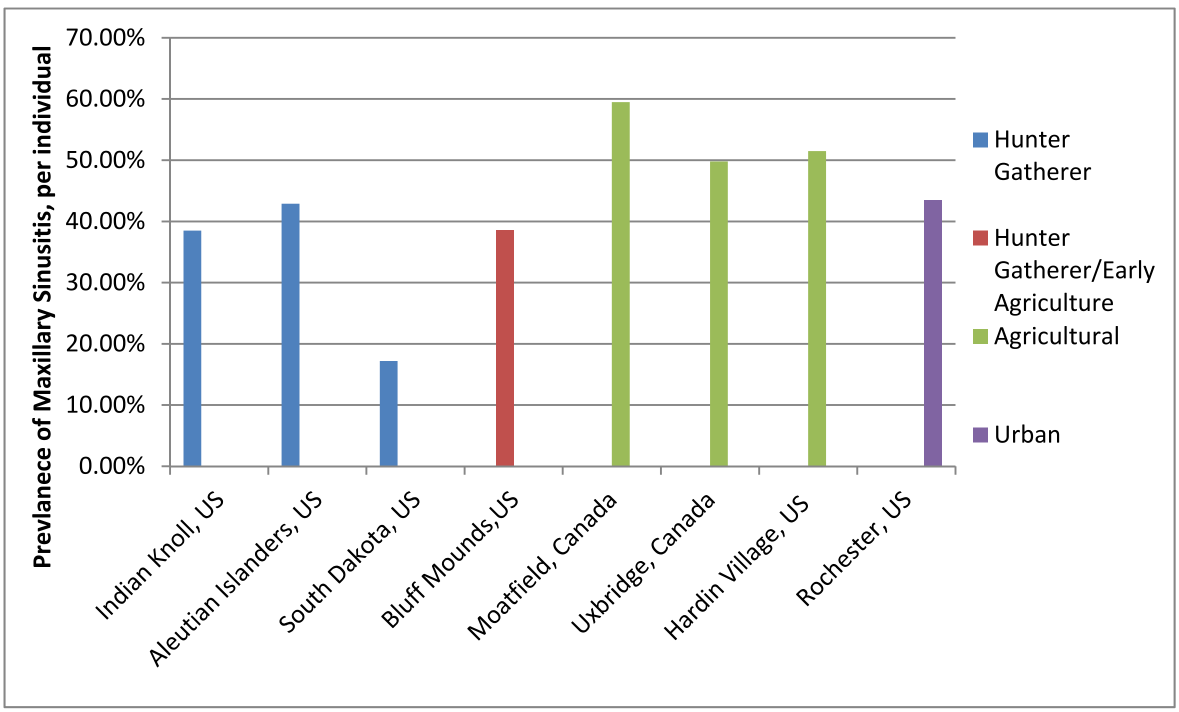


Figure 2.6: Previously analysed populations from North America arranged by economy.

From a single Iroquoian internment event in Southern Ontario, Canada (AD 15th C) Merrett and Pfeiffer (2000) found 103 (49.8 %) chronic maxillary sinusitis in 207 individuals, including juveniles. Merrett (2004) found 44 (59.5%) of 74 maxillae had evidence of sinusitis at the Moatfield site in Ontario, Canada (AD 1300). Both populations, despite being hunter-gatherer groups, would have lived in long houses with central hearths, which would have caused a smoky environment.

Lew and Sirianni (1997) found 26 (43.5%) of 60 skulls from a poorhouse (AD 1826-1855) in Rochester, New York, had evidence of remodelling in the maxillary sinuses. Roberts (2007) found 17 affected individuals (51.5%) at the rural agricultural site of Hardin Village, Kentucky (AD 1150 to 1675), 15 affected individuals (42.9%) from seven hunter-gatherer populations in the Aleutian Islands, mostly in modern day Alaska (AD 1500-1600), 37 affected individuals (38.5%) at the rural hunter-gatherer site of Indian Knoll, Kentucky (4570-3500 BP), 27 affected individuals (38.6%) at Bluff Mounds, Illinois, a site that spanned hunter-gatherer and agricultural subsistence methods (AD 800-1100), and 15 individuals affected (17.2%) from 11 seasonal hunter and gather populations from South Dakota (late AD 1500- early1800).

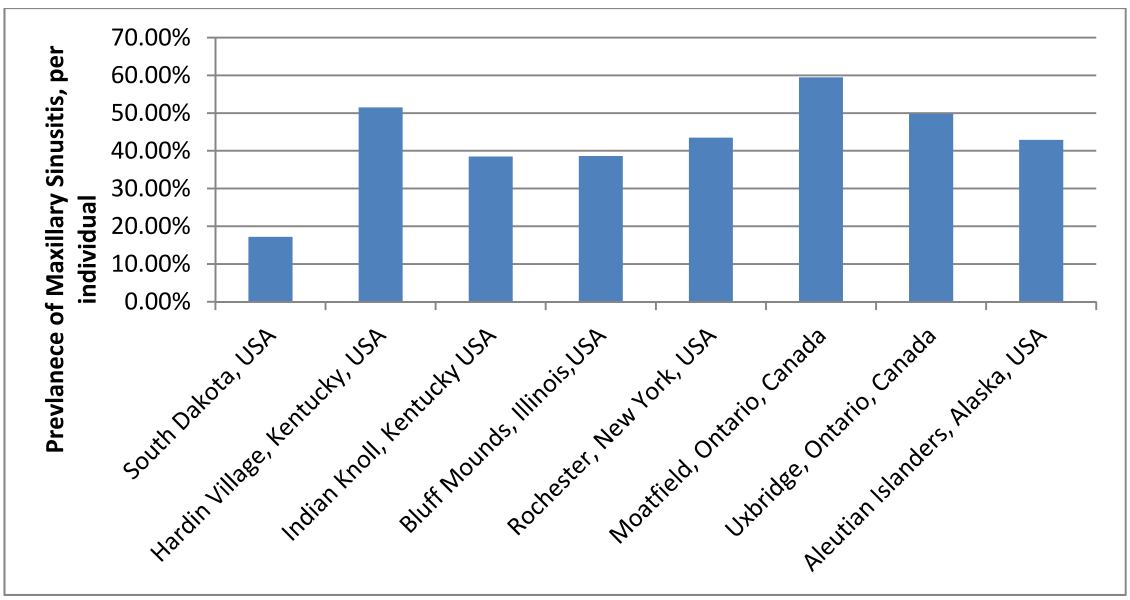


Figure 2.7: The previously recorded sites from North America arranged by latitude, from most southern to most northern.

These samples come from a very large area, with vastly different climates and lifestyles and cover a very wide range of time and various subsistence economies. When the sites are arranged in order of subsistence economy (see Figures 2.6) or by latitude (see Figures 2.7), which should be a relatively reliable indicator of average annual temperature over such a large area, there is no perceivable pattern in the prevalence of chronic maxillary sinusitis.

2.2.2.2.3 Africa

Africa	**Location**	**Dates**	**Description**	**N**	**n**	**%**	**Reference**
Kulubnarti	Sudan	AD 500-1700	Agriculture/ Rural	101	22	21.8%	Roberts 2007

Table 2.6: Prevalence of chronic maxillary sinusitis from Kulubnarti, Sudan

At Kulubnarti, in Sudan (AD 500-1700), 22 (21.8%) individuals with at least one sinus preserved had chronic maxillary sinusitis in the agricultural population (see Table 2.6). Given the relatively warm and dry environment, it might be expected that the result would be lower here, which it is. However, if individuals in this environment were exposed to high concentrations of particulates in the air, specifically those small enough to reach the upper airway, this could also lead to higher prevalence rates.

2.2.3 Rib periostitis

There has been very little research done on the prevalence of rib periostitis in populations. As mentioned earlier in this chapter, much of the research on these lesions has attempted to link them to tuberculosis, with varying success. Kelley and Micozzi (1984) investigated the Hamann-Todd collection and found only 8.8% of individuals with a cause of death listed as TB also had rib periostitis on the visceral surface of the ribs. Roberts *et al (1994)* found that of 1,718 skeletons in the Terry Collection, which dates from the twentieth century, with a known cause of death, 24.4% had rib periostitis. Of these, 52.1% had pulmonary disease listed as the cause of death, and 61% of these were a result of tuberculosis. It is possible the approximately 48% of individuals who did not have pulmonary disease listed as the cause of death had suffered from chronic respiratory infection at some point not long before their death, which led to the remodelling on their ribs. However, if this is not the case there may be some other cause of these lesions, such as inhalation of poor air quality over a long period of time, leading to respiratory disorders. In the Identified Skeletal Collection from the Museu Antropológico at the University of Coimbra in Portugal, Santos and Roberts (2006), found 90.9% of juveniles and 85.7% of adults diagnosed with TB also had accompanying rib periostitis. These differences in prevalence could result from the different locations and time periods. Rib periostitis would only occur after the individual had suffered from the condition for long enough period of time for the bone to remodel. If the individuals in one population were far more likely to die quickly without having had time for bone remodelling, while another populations suffer chronically from the condition, this could explain any discrepancies.

There are very few instances where the prevalence of rib periostitis has been calculated for the whole population. Capasso (2000) found 11.6% of the well-preserved remains from Herculaneum, Italy (AD 79) displayed rib periostitis. They were evenly distributed by age and sex, suggesting the cause was common to the whole population. In the home there would have been a high degree of particulate pollution caused by burning animal and vegetable oil in lamps, cooking various materials, and burning wood, other plant matter, and animal dung for heat. This could be the cause of the respiratory conditions that caused the rib periostitis.

In England there have been no published articles specifically on rib periostitis. The prevalence rates are typically reported in skeletal reports, if reported at all. Unfortunately, as with chronic maxillary sinusitis, it is possible that their lesions are going unrecorded unless they are particularly severe manifestations. Roberts and Cox (2003) included a comprehensive summary of the prevalence rates reported in published and unpublished literature for populations in Britain. Their results were presented as crude prevalence rates, as this was the only way to compare the data from so many sites, which, did not necessarily report their results in the same manner. As a result the prevalence rates given below are expected to be considerably lower than the rates recorded in this study, as these prevalence rates only included individuals with preserved ribs.

Two cases of inflammatory rib periostitis have been found in Britain from the Neolithic period, at Hazelton, Gloucestershire and Hambledon Hill, Dorset. One case each was found in each of the Bronze and Iron Ages (Roberts and Cox 2003). It is possible that these prevalence rates are accurate, given the generally small number of preserved skeletal remains from these periods. However, this may represent an underestimate if the ribs were not carefully examined during osteological analysis of most populations from this period.

The prevalence of rib periostitis increases slightly in the Roman Period. Forty-five (0.3%) of the total individuals recovered from various Romano-British sites were recorded as being affected. In the Early Medieval Period the prevalence rises slightly again. Thirty-three individuals (0.5%) from various Early Medieval sites have rib periostitis. Jakob (2004) found no cases of rib periostitis from 495 ribs at Norton I (AD 6th-8th C). At Apple Down in Compton, Sussex (5th-8th C AD), of 1,363 ribs 42 (3.08%) had periostitis and at Castledyke South, near Barton-on-Humber, Lincolnshire (AD 6th-7th C), of 1,125 ribs, 36 (3.2%) had rib periostitis (Jakob 2004). The rise in the prevalence of lower respiratory conditions may occur for the same reasons as the chronic maxillary sinusitis. From the prehistoric period to the Roman Period the houses became less well ventilated and in the Early Medieval Period the population began to carry out more daily activities indoors, increasing their exposure to smoke. It may also be caused by increased exposure to lower respiratory infection. Not all of these infections will cause other pathological bone changes, and therefore the cause is not always visible in the palaeopathological record.

2.3 Summary

While smaller studies have hypothesized about the causes of sinusitis and rib periostitis, there are no large studies that have attempted to test these hypotheses to determine whether they are sustainable. As has been seen, while some studies support the hypothesis that sinusitis is related to air quality, other individual populations or studies may prove that hypothesis false. But, it is unclear whether these instances where the hypothesis is contradicted rule the hypothesis out entirely, or there are some factors we do not yet understand affecting the prevalence at these anomalous sites and no other population. It is clear from the debates within clinical literature that the causes of sinusitis are numerous and not well understood. This study will attempt to disentangle these causes in archaeological populations, in order to determine if any cause can be ruled out or if any were clearly more predominant. All of these archaeological sites will be discussed further and more information will be given about their context in the following chapters.

3 Historical and Environmental Context

3.1 Introduction

In order to understand how and why populations in the past developed respiratory disease it is necessary to understand the relevant lifestyle factors, including their environment that could lead indirectly or directly to respiratory disease. Since this study covers a period of almost three thousand years, this discussion of the historical context will present a broad overview of the factors that are visible in archaeological and/or historical records and can relate directly or indirectly to respiratory disease. Details specific to the samples analysed in this study are given in Chapter 4.

The time periods defined in this study are relatively arbitrary from the view of the people alive at those times. They are based on large political and social changes, which, while they may have affected the lives of the populations analysed, may have occurred over relatively long periods of time and in a manner that varied geographically throughout the country. On the cusps of these periods, much of the population would have continued to live as they always did (Roberts and Cox 2003). To limit the effect of this, where possible, the sample populations chosen for this study from each period were taken from cemeteries temporally distinct from the populations of the preceding and proceeding periods. This aspect of the sample selection will be discussed further in the next chapter.

Conversely, large lifestyle changes, for example, precipitated by changes in religion or extensive epidemics, occurred within the time periods defined in the following sections rather than at their beginning or end. These changes had an equally large, or even larger, effect on the general lifestyle of the population than the changes that were used to define the periods. For example, lower population density and increased availability of resources following the plague epidemics in the Late Medieval Period, lead to a general improvement in the lives and living environments of the lower status groups (Dyer 2000). However, the cemeteries from which the human remains were excavated could have been in use throughout this period and incorporated both individuals who died before the epidemics and those who survived long after. As a result, any change in the prevalence of respiratory disease caused by improved lifestyle just after the plagues would be less visible. This is a problem of the general lack of stratigraphic data for cemetery sites; it is usually not possible to differentiate different phases of a cemetery in order to see changes in disease frequency and relate frequency to factors in people's lives that could have led to those changes.

This chapter will discuss three main areas of the historical background that are most likely to affect the prevalence of respiratory disease, based on previous clinical and archaeological literature on indoor pollution, occupation and climate. Air pollution has been one of the most commonly cited causes of respiratory disease in the clinical and bioarchaeological literature (see Sections 2.1.2 and 2.1.3). However, indoor air pollution is affected by a number of factors including house type, plan and structure, building materials, amount of dust and animal dander, type of fuels, how the fuels are used, and how frequently and for how long the population is exposed to poor air quality. In addition to air pollution in the domestic environment, occupation may also expose an individual to high concentrations of pollution throughout the day for much of their lifetime, making a considerable contribution to overall exposure to air pollution. For this reason, evidence of occupation is essential for fully understanding the results of this study. However, some industries were known to create so much air pollution that they did not just affect those performing the work, but the whole population living near the work places. For example, lime, which was essential for building construction, was one such industry which was known to contribute to atmospheric levels of pollution during the summer when concentrations of domestic smoke would be at their lowest (Brimblecombe 1987). In addition to more localised sources of air pollution there are larger scale atmospheric factors that can increase the prevalence of respiratory disease. It is important to understand the climate and subsequent weather to which these populations were exposed because this affects not only the functioning of the respiratory system through temperature and humidity (Jones 2001), but also affects the quality of the air, by affecting vegetation and topsoil (Ayres 2009) and the ability of a building to ventilate (Beck 2007). For the purpose of this study climate is made up of multiple factors, including temperature, rainfall, and humidity prevailing over a long period of time. As weather is defined by short term (weeks) changes in these factors, weather is not discussed in this study. Climate may also affect the lives of the populations being studied as it may cause increased fuel use, or increase the time spent indoors in colder climates (Ayres 2009).

3.2 Indoor spaces and respiratory disease

As was discussed in Sections 2.1.1, 2.1.2, and 2.1.3, indoor spaces account for the vast majority of respiratory disease that result from exposure to poor air quality (World Health Organisation 2006). The sample populations in this study needed to be selected to contrast assumed higher and lower exposure to poor air quality, but to do this it is first necessary to examine current understanding of the living environments of different populations from these periods in England.

Burning fuels would have been the only method of providing heat, hot food, and light when they were needed. There are clean burning fuels, such as natural gas, but these would not have been used by past populations. In the past, as in many living populations in developing countries, fuels that when lit do not combust completely, leaving chemicals and particulates in the air, would have been the only source of heat and light (Albalak *et al.* 2001; Balakrishnan *et al.* 2002; Boman *et al.* 2006; Brauer *et al.* 1996). These fuels would subject any inhabitants of buildings to high concentrations of chemical irritants and particulates, which would lead to high levels of various forms of respiratory disease (Bruce 2002; World Health Organisation 2006). This effect would be further enhanced if the ventilation of the building was poor and the smoke unable to escape through the roof or elsewhere. This would lead to increasing levels of smoke compared to buildings where smoke could escape through the roof in some way, for example via a chimney/through a thatched roof (Chen *et al*. 1990; Matson and Sherman 2004; Schwela 1997).

Ideally, when there is complete combustion of a fuel, the only by-products are carbon dioxide and water vapour, but no biomass fuels combust completely (Demirbas 2008). As a result, other compounds are released. Precisely what by-products are created and in what concentrations depends heavily on the fuel being burned (Demirbas 2008). All incomplete combustion equations create forms of carbon, such as carbon monoxide, and particulate matter, and fuels containing nitrogen and oxygen create nitrogen and sulphur oxides (Demirbas 2008). A summary of the effects on human health from these by-products are given in Table 3.1.

Pollutant	Mechanism	Potential health effects
Particulate matter: small particles less than 10 microns, and particularly those less than 2.5 microns aerodynamic diameter	• Acute: bronchial irritation, inflammation and increased reactivity • Reduced muco-ciliary clearance • Reduced macrophage response and (?) reduced local immunity • (?) Fibrotic reaction • Autonomic imbalance, pro-coagulant activity, oxidative stress	• Wheezing, exacerbation of asthma • Respiratory infections • Chronic bronchitis and COPD • Exacerbation of COPD • Excess mortality, including from cardiovascular disease
Carbon Monoxide	• Binding with Haemoglobin (Hb) to produce COHb which reduced O2 delivery to key organs and the developing fetus.	• Low birth weight (fetal COHb 2-10%, or higher) • Increase in perinatal deaths
Benzo[a]pyrene	• Carcinogenic (one of a number of carcinogenic substances in coal and biomass smoke)	• Lung cancer • Cancer of mouth, nasopharynx, and larynx
Formaldehyde	• Nasopharyngeal and airways irritation • (?) Increased allergic sensitisation	• (?) increased susceptibility to infections • (?) May lead to asthma
Nitrogen dioxide	• Acute exposure increases bronchial reactivity • Longer term exposure increases susceptibility to bacterial and viral lung infections	• Wheezing and exacerbation of asthma • Respiratory infections • Reduced lung function (children)
Sulphur dioxide	• Acute exposure increases bronchial reactivity • Longer term: difficult to dissociate from particulate effects	• Wheezing and exacerbation of asthma • Exacerbation of COPD, CVD
Biomass smoke (component uncertain)	• Absorbtion of toxins into lens, leading to oxidative changes	• Cataract

Table 3.1: Emissions from biomass fuels and their effects on human health (Bruce** et al**. 2002) Lens refers to the lens of the eye, for COPD (see Section 2.1.1) and CVD is short for cardiovascular disease.

The materials from which a house is constructed can heavily dictate the amount of ventilation in a structure, but far more important than the type of materials is the way they are used. While a thatched roof will allow air to pass through it, tiles on a roof will allow little or no air to pass through, unless the tiles or the roof are intentionally altered to allow for ventilation, e.g. via a chimney, or curved tiles to allow air to pass underneath them. Openings in the gable ends of the roof that would allow air out but not allow precipitation in could be incorporated in the roof, and large windows would also aid in the removal of air pollutants, as long as they are opened for periods of time (Johnson 1993). These materials and features have been used differently throughout English prehistory and history, in different environments, and between the social classes. Given this, it is expected that there would be differences in exposure to air pollution in populations regionally and temporally.

However, determining a population's exposure to poor air quality is more complex than understanding house structure and building materials, or recognizing the types of fuels used and how or where they were used. Archaeologists can make inferences about, or even have proof of, the building materials used in a particular period. They may even have evidence of intentional modifications to a particular house that would increase ventilation. However, we cannot know the amount of exposure individuals would have had, which would depend heavily on the time they spent exposed to the air inside the building (Bascom and Kesavanathan 1997; Bruce *et al*. 2002), the unique morphology of each individual's respiratory system (Bascom and Kesavanathan 1997; Heyder *et al*. 1986; Kim and Hu 1998), the rate of respiration (Heyder *et al*. 1986; Kim and Hu 1998), and the size of the particulates (see Figures 3.2 and 3.3), among others (see Section 2.1.2). This question is further complicated by the fact that many populations in the past would have wanted a certain concentration of smoke in the home, because smoke would have been considered a resource. Most populations believed it would harden timbers and keep the household healthy (Brimblecombe 1987) which, to some extent, has been proven true in clinical studies (Braithwaite *et al*. 2008). Smoke was also used to dry crops and preserve meat (Letts 2000). In addition to smoke in the air, soot would have built up on the underside of the thatched roof, up to several centimetres thick. It would be toxic to most organisms, and so would deter the growth of fungus as well as preventing infestation by insects or rodents (Letts 1999). The thickness of the layer would also make it less likely that a spark from a fire could reach the thatch and therefore limited the likelihood of fires (Letts 1999).

In the following section, for each time period, the Iron Age, Roman, Early Medieval, Late Medieval, and Post Medieval Periods, the current understanding of the predominant settlement types, house types, fuels, and the ways in which they were used, are discussed in order to assess the relative expected prevalence of respiratory disease in the population.

3.2.1 Iron Age

The Iron Age in England spans the eighth century BC to the first century AD (Haselgrove 2006). More than six thousand Iron Age settlement sites have been recorded. These range in size from single farmsteads to hillfort settlements that may have housed hundreds of individuals (Haselgrove 2006; Henderson 2007). However, most of the settlements were single farmsteads, which would have been up to a hectare in area (Cunliffe 2005; Haselgrove 2006). The population living in these settlements would have practiced agriculture, planting crops and raising domestic animals, most frequently cattle and sheep (Haselgrove 2006). It is also clear from the analysis of pollen samples that the scale of agriculture during this period changed the landscape of Southeast Britain considerably by using up a large percentage of forests and making land more ideal for agriculture (Haselgrove 2006; Henderson 2007). Larger communities, in the form of hillforts became more common in the latter part of the Iron Age, although it is unclear why. It may relate to status or defence (Cunliffe 2005). Most of these sites remained relatively small serving fewer than 14 households while some, such as Danebury, Hampshire and Maiden Castle in Dorset, were notably large and elaborate by comparison.

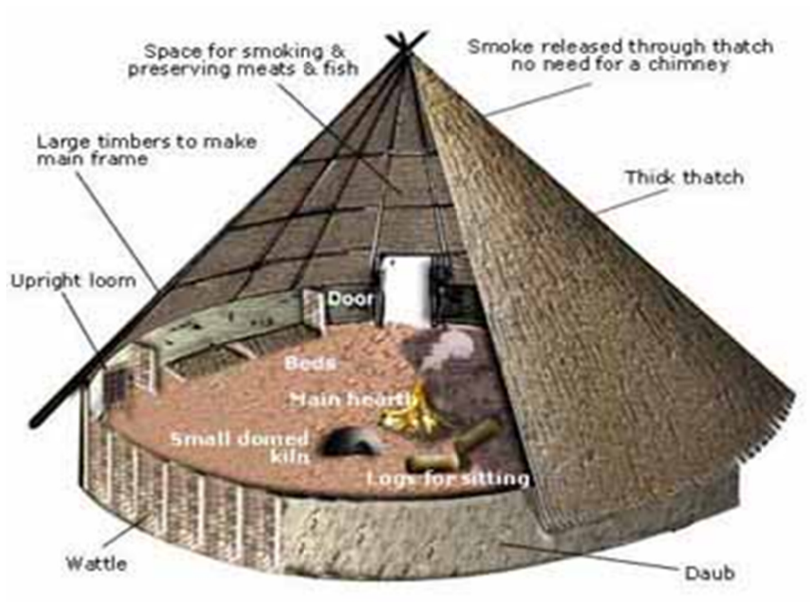


Figure 3.2: Reconstruction of the layout inside of an Iron Age round house based on an Iron Age settlement called Chysauster in Cornwall *http://www.bbc.co.uk/history/ancient/british_prehistory/ironage_intro_01.shtml*

Based on archaeological excavations of Iron Age sites, the most common structures, called round houses, were circular between six and 15 metres in diameter with one door (Cunliffe 2003; Harding 2009; Haselgrove 2006). The walls were made either of timber planks or wattle and daub (see Figures 3.2 and 3.3). Given that they were made of organic materials, roofs are very rarely preserved. Based on what has been recovered, and inferences based on the crops and vegetation nearby, it is believed that they were conical in shape and thatched with reeds (Cunliffe 2003; Harding 2009; Haselgrove 2006). This likely would have allowed for good ventilation. In Southeast England rectangular buildings with wattle and daub walls start appearing in the late Iron Age (Haselgrove 1999).

The houses would have had several uses and it is possible that individual families may have had several buildings with different functions, for example for sleeping, cooking, craft production or for housing animals (Cunliffe 2003; Cunliffe 2005). In addition to this house type, post structures have been found where the floor was raised on a platform between one and 1.5 meters high. The walls were made of wattle with daub to protect it from water, and the roof would likely have been thatched with reeds or straw (Cunliffe 2003). It is unclear what these structures were used for, but there are several theories for the function of the structures including as barracks, as platforms to expose the dead, or watchtowers, or granaries (Cunliffe 2003). Unfortunately, since the exact use of these structures in not well understood, it is also impossible to fully understand how, or if, this would affect the populations' exposure to particulates in the air.

Figure 3.3 : Reconstruction of an Iron Age roundhouse at Flag Fen, Cambridgeshire *http://www.stone-circles.org.uk/stone/flagfen.htm*

3.2.2 Roman Period

The population of Britain during the Roman Period remained primarily rural. However, some towns were created during this period. The combined population living in these towns would have been considerably smaller than the combined population living in the countryside. Millett (1995) estimated the rural population of Britain at approximately 3.6 million and the urban population as only 250,000, with 125,000 being made up of the army. Unfortunately, excavations of Roman cemeteries associated with towns vastly outnumber those associated with purely agricultural settlements, which makes comparison of urban and rural environments difficult (Hope 2000; Taylor 2007).

Figure 3.4: Reconstruction of a Romano-British House from Hinchingbrooke Country Park, Cambridgeshire

In Southeast England rural settlements were typically farmsteads or hamlets surrounded by enclosures. While rectangular houses start to appear in Southeast England in the Late Iron Age, the rural population in Britain continued to live in round houses (see Figures 3.4 and 3.5) as late as the fourth century AD. Rectangular houses (see Figure 3.6) became the more dominant house structure by the second century. These structures could be both one-roomed or multi- roomed, with a central hearth. In some cases, these buildings would also be used for housing animals (Ellis 2000). As in the previous period, houses were typically constructed of wattle and daub walls with thatched roofs. However, stone was occasionally incorporated into the structure in order to increase its longevity, and in some cases, stone was the primary building material, particularly for high status households (de la Bedoyere 2001).

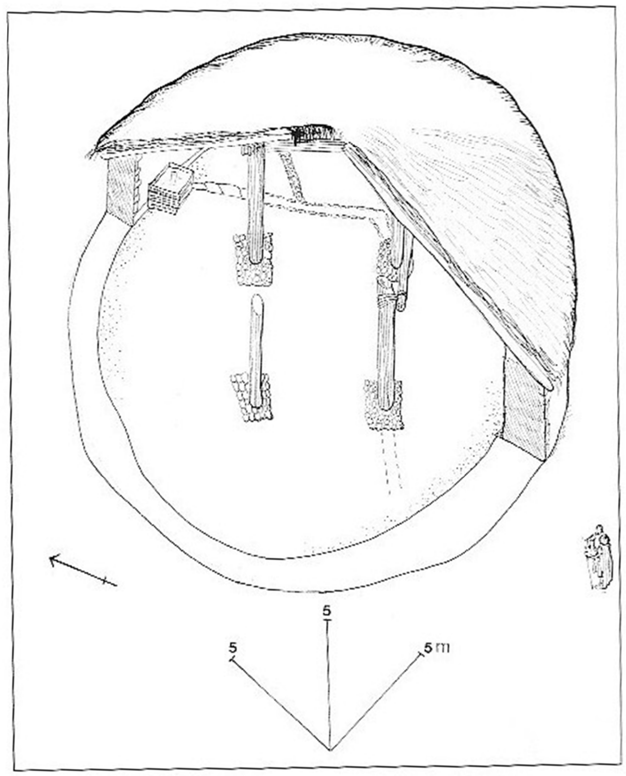


Figure 3.5: The internal layout of a Roman roundhouse from Winterton, Lincolnshire (de la Bedoyere 2001: 141)

London was the largest town in Roman Britain with an estimated population of 30,000 people (Millett 1990). Towns were centres for administration, industry, and trade. In some cases, they provided new opportunities, which drew some of the population from the rural environment (Barber and Bowsher 2000). It is possible that the migration of so many individuals would have led to their exposure to new infectious diseases (and no immune resistance), while higher population density in towns would allow pathogens to flourish more so than in the more dissipated and less dense rural populations. However, in some cases, towns improved levels of hygiene by providing drainage systems, latrines, and bathing houses (Barber and Bowsher 2000).

The higher status buildings were much more likely to be built out of non-organic material, such as stone, and therefore are more likely to be preserved. This has led to a bias in the archaeological record towards these buildings (de la Bedoyere 2001; Lethaby 2007). Houses in towns were in many cases two storied and terraced, fronting onto the street, in some cases, with workshops or shops on the ground floor. If activities carried out in the workshops produced large amount of air pollution this, in addition to the usual domestic air pollution, could have increased the levels of pollution throughout the entire domestic space. By contrast, lower-cost housing inhabited by lower status individuals could be limited to one or two rooms on one level, which would have functioned both as a domestic space and as a workshop (de la Bedoyere 2001; Lethaby 2007). This much smaller space would have even higher concentrations of poor quality air depending on the amount of ventilation the space allowed and the types of activities carried out. Only the wealthiest would have had large multi-roomed spaces where each room had its own associated activity, and some wealthy individuals chose to build homes in a Roman style (Perring 2002). The features that defined these homes were painted plaster walls, tiled roofs, window glass, and hypocaust heating (a series of channels below a timber floor, which conducted hot air from a furnace outside the home either to heat a single room or, for the wealthiest households, through the whole building). Unlike a central hearth, a hypocaust would protect the inhabitants from much of the smoke created by the combustion of biomass fuels. Unfortunately, the skeletons of individuals who lived in these house types were not available for this study (Perring 2002).

Figure 3.6: Reconstruction of a Romano-British House from Upton Country Park, Dorset
http:\\www.strollingguides.co.uk

3.2.3 Early Medieval Period

The end of the Roman Period at the beginning of the fifth century is defined by the end of Roman control in Britain. From AD 410, Roman towns went into disuse and the country was once again almost exclusively rural, with the possible exception of small market towns (Blair 2003; Lapidge *et al*. 2001; Russo 1998). It was only in the seventh century that more urban environments were readopted.

With the influx of Saxon traditions into the population, and the incorporation of some traditions from the lowlands of continental Europe, two types of houses increasingly dominated in England in this period, grubenhaus, or sunken buildings constructed of wattle and daub walls with wooden floors, below which food could be stored, (see Figures 3.7, 3.8, 3.9) and hall houses, or the precursors to the standard open hall medieval houses seen later (Hamerow 2002). As in the previous periods these would have been constructed of wood, wattle, daub, and thatch on the roof. Grubenhaus were more common in eastern England, while halls appear to be more common south of the River Thames, in places such as Hampshire (Hills 2006). Due to the lack of materials recovered and lack of historical documentation, the exact uses of buildings from this period, as with the previous period, are not always clear. It is possible that some buildings were used for storage or other activities rather than as domestic space.

The specific design and size of houses changed throughout this period. Unfortunately, their exact dating, due to the poor preservation, makes it difficult to assign a particular design to a specific time (Hamerow 2002). Based on the few houses that can be dated confidently, there appears to be patterns in the types of buildings. Houses in the fifth century were typically small, and rarely more than 12m long. By the seventh century larger halls of more than 150m^2 were built, but houses as short as 6m in length were also common. From the sixth century through to the end of this period, trench foundations became increasingly common, and about one quarter of houses throughout this period contained an internal partition; what activities were carried out on either side of this partition is not known (Hamerow 2002).

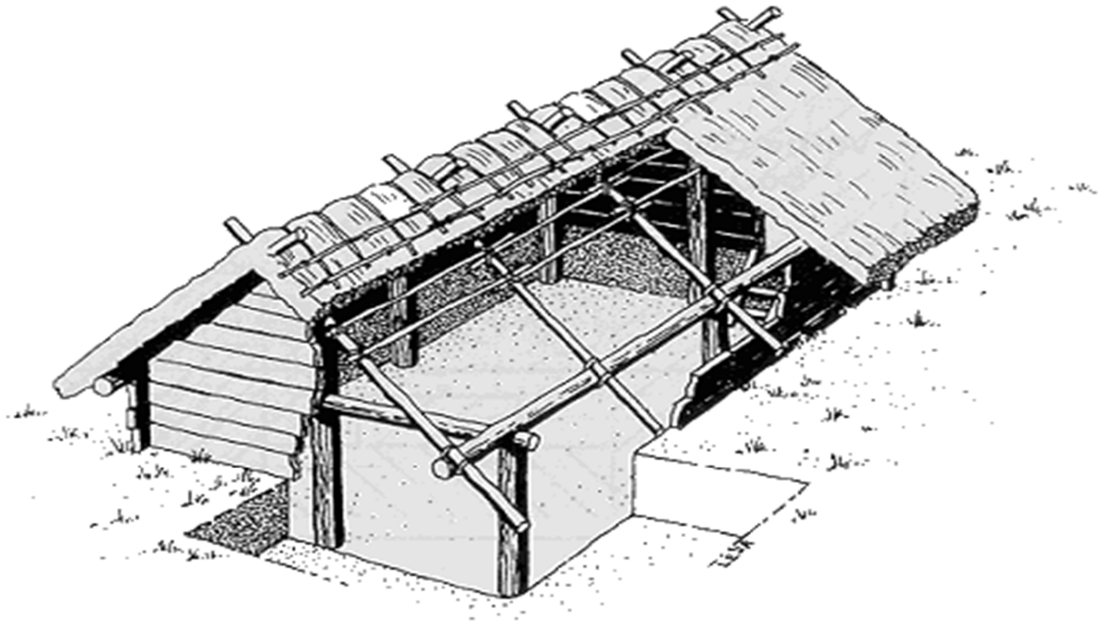


Figure 3.7: An example of a grubenhaus
http://www.rosstal.de/vereine/heimatverein/heimatblaetter/heft27.htm

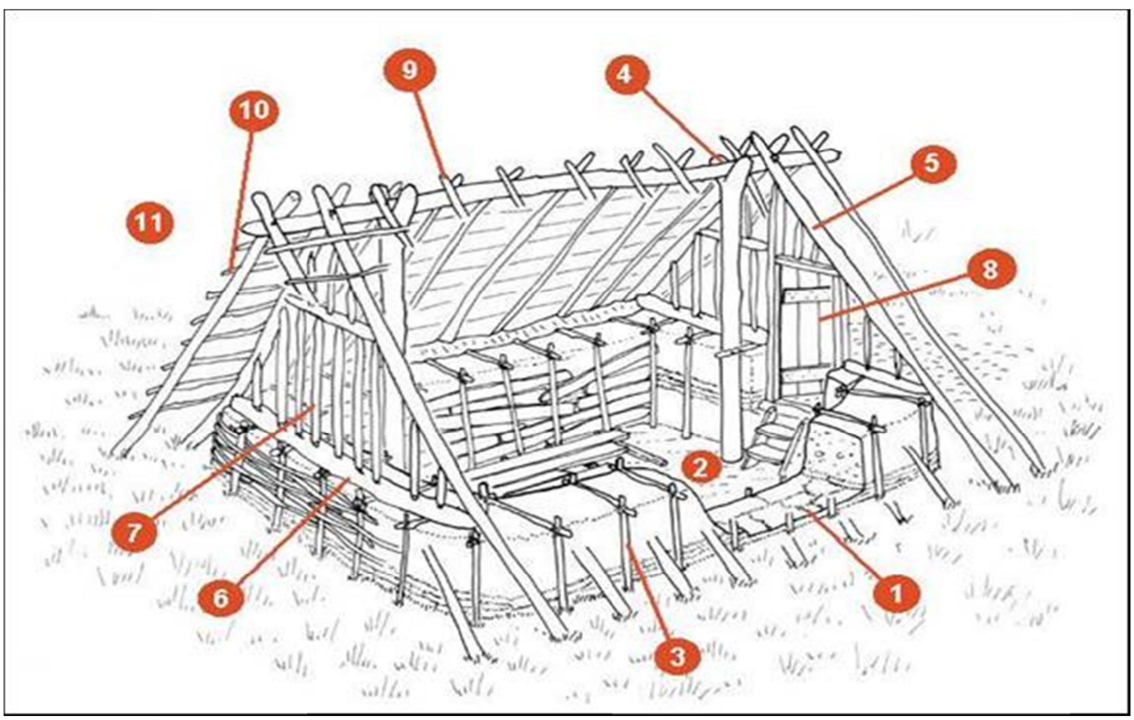


Figure 3.8: Reconstruction of a grubenhaus with a different layout *1) Turves removed from pit area and laid as base of surrounding walls 2) Pit dug and earth piled around edges 3) Earth formed into walls, and shored-up on both sides 4) Ridge posts and beam set up 5) Main rafters set up 6) End wall plates laid 7) Framing of end walls 8) Well-fitting*

door inserted 9) Rafters set-up 10) cross-pieces fixed to hold thatch 11) Roof thatched, and end walls daubed. Interior cracks sealed with clay. http://www.archaeoart.co.uk/structures/sunken_featured_building.htm

There is little known about settlement patterns in the Early Medieval Period. Most excavations that examine small areas find individual houses with no physical evidence of the methods used for the demarcation of land for keeping domestic animals next to settlements, such as fences. Larger excavations, such as at Mucking, Essex, and West Stow, Suffolk (Hamerow 2002; West 1986) found that settlements were probably made up of approximately ten households at any given time. At Mucking, the settlement would have covered an area of 18 ha. These settlements would not likely have generated as high a concentration of particulate matter in the air outside the home as they would have in crowded urban environments. Again, since little more than postholes remain of most buildings, it is possible that not all of the buildings represent homes. Different activities may have been carried out in different buildings, and separate buildings may have been used for activities such as craft production. This practice was common in some parts of continental Europe and is recorded in England in the AD 10th century (Dölling 1958). It is believed that, in Britain in this period, animals were housed separately from the living area, unlike in other parts of Europe, and therefore some buildings may have been dedicated to housing animals (Hamerow 2002). It is difficult to discuss the fuels used, how the houses were heated and potential smoke exposure. Unfortunately, very few houses from this period contain evidence of a hearth, although they were almost certainly used. This may be a result of poor preservation (Hamerow 2002).

Figure 3.9: Reconstruction of Early Medieval buildings in West Stow, Suffolk

3.2.4 Late Medieval Period

The Late Medieval Period extends from the mid- 11th to the 16th century. During this time, the population can be divided into rural and urban (see Section 1.1). Towns grew out of a need for market centres where the rural population could bring their produce to sell and could acquire what they needed for their farms and households. Whereas only 2% of the population lived in towns in the mid ninth century, by the mid to late eleventh century that number had grown to approximately 10% (Dyer 2002). Towns in England were also the centres for trade and industry as they were close to the consumers and typically sited next to rivers or the sea and with access to road networks to aid transport of goods. The population density in some towns (e.g. Winchester, Hampshire) reached an estimated 81 individuals per acre (Dyer 1998), and the population of London, the largest town, has been estimated at over 10,000 (Dyer 2002).

By the end of the Early Medieval Period, construction of buildings became more sophisticated (Dyer 2000). Buildings in towns were made out of three basic materials, timber, stone, or brick. Stone buildings were typically only built by wealthier individuals, while brick, in spite of being produced from the 13th century, only became common in construction after the 15th century. Earth buildings were also rare in southeast England. Most often the buildings were constructed of wood, although these are much less likely to survive in archaeological contexts than the higher status stone buildings (Schofield and Vince 2003). While houses in the early part of the period were typically only one storey, by the end of the period some houses in towns were up to four storeys high (Dyer 1998), and in some cases, from the 13th century, the first storey of the house would be built from stone in order to increase the longevity of the building (Dyer 1998). The roof would still be made from thatch, although an opening might be left to further aid the smoke in escaping (Johnson 1993). The poor, however, lived in less comfortable surroundings. In many cases, poorer households could afford only single rooms with a wattle and daub wall structure and straw on the ground as flooring. Spaces would have had no kitchen area, water supply, or latrines (Olsen 1999). Such small spaces would have filled up with smoke more quickly if fires were used, with irritation of respiratory tracts likely to result and the high density of people enabling the transmission of infection.

Houses in rural environments continued to be timber-framed with wattle and daub wall and thatched roofs (see Figure 3.10). The walls were likely plastered and lime-washed. Buildings from before the 14th century are rarely found in archaeological contexts, prompting some to suggest they were poor quality (Dyer 2000), though this is not necessarily the case. Throughout the Late Medieval Period, open halls, much like those described in section 3.2.3, were adopted as a basic layout by high and low status people (Johnson 1993), although they would have differed in size and quality. The centre of the building would be an open area used for most activities, including sleeping, while partitions would separate spaces at either end of the building for activities such as preserving food, as well as possibly housing animals (see Figure 3.11) (Johnson 1993).

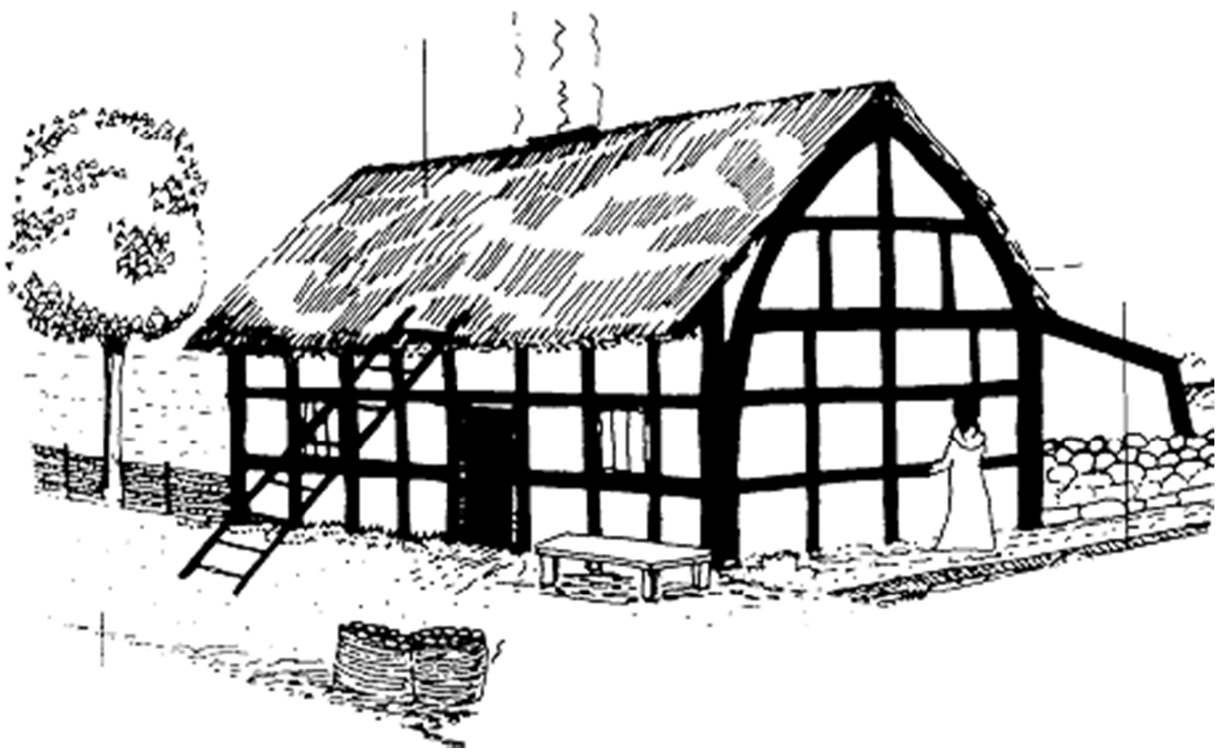


Figure 3.10: Example of a rural Late Medieval Timber framed house
http://www.cpat.org.uk/educate/leaflets/houses/houses.htm

In the early part of the period, houses would have only had one storey and all activities would have taken place near the floor where the concentration of smoke was lowest, as in the previous period (Letts 2000). When rooms were built above the first floor, later in the period, an unobstructed path to the roof would typically be left over the hearth so the smoke could rise above people's heads and escape through the roof (Emery 2007; Platt 1994) (see Figure 3.6). How much smoke was allowed into each room and allowed to remain in a room most likely depended on the purpose of the room and the individuals' comfort (Brimblecombe 1987; Emery 2007; Letts 2000). Where possible, windows were placed on either side of the hall, and shutters and slats could have been opened and closed in order to regulate the amount of ventilation in the room (Johnson 1993).

After the plague epidemics of the 14th century, the population decrease made the political system less and less stable. The lower status population found their labour more in demand, which made them more valuable, and this increased income allowed them to spend more time and money on their homes. Homes were likely high quality and built by skilled builders and carpenters (Dyer 2000). After the 14th century, they were typically built on top of stone foundations which would prevent the wood frame from being exposed to damp and provide a more level surface for the roof (Dyer 2000). The household might also have included one or more outbuildings to house animals, store crops, and carry out other activities, such as crafts, brewing, or baking, but the number and quality of the outbuildings would depend on the status and wealth of the household (Dyer 2000). Unfortunately, unlike some higher status housing, the lower status housing rarely survives to the present, and for this reason there is less known about these structures.

Although the population had the technology to build and use chimneys throughout much of this period, until the 16th century when there was an almost universal use of coal, populations chose to live in open halls with open hearths. This style probably kept the household together (Johnson 1993). From the 13th century AD, hearths were typically moved from the central room to the cross passage and a hood placed over the fireplace to reduce the amount of smoke in living areas (Dyer 1998). Wood was the predominant fuel for heating and lighting. However, sea-coal was also a somewhat common fuel with an estimated 600 tons of sea-coal burned annually compared to 40,000 tons of wood (Dyer 1998).

In addition to windows in the hall, houses could have had open gablets (Emery 2007; Johnson 1993; Platt 1994). As smoke rose to the roof it could then escape through these openings in the roof regardless of the type of roofing material used. Similarly, houses could also have had louvres (Emery 2007; Johnson 1993; Platt 1994). These could have been anything from a simple flap in the roof that could be opened and closed to allow air in and keep precipitation out, to more sculptural pieces sitting on the roof of more wealthy homes (Emery 2007; Johnson 1993; Platt 1994). These louvres may also have been convenient in urban contexts where smaller properties backing onto neighbouring houses and cesspits would have made the type of windows associated with ventilating open halls impossible (Emery 2007; Johnson 1993; Platt 1994). However, it is impossible to say how common these louvres were, even where the houses survive to the present. In some cases the louvres themselves remain or leave some trace of their previous existence on the structure of the house, but the smaller of these might have sat between the rafters and left no trace at all (Emery 2007; Johnson 1993; Platt 1994).

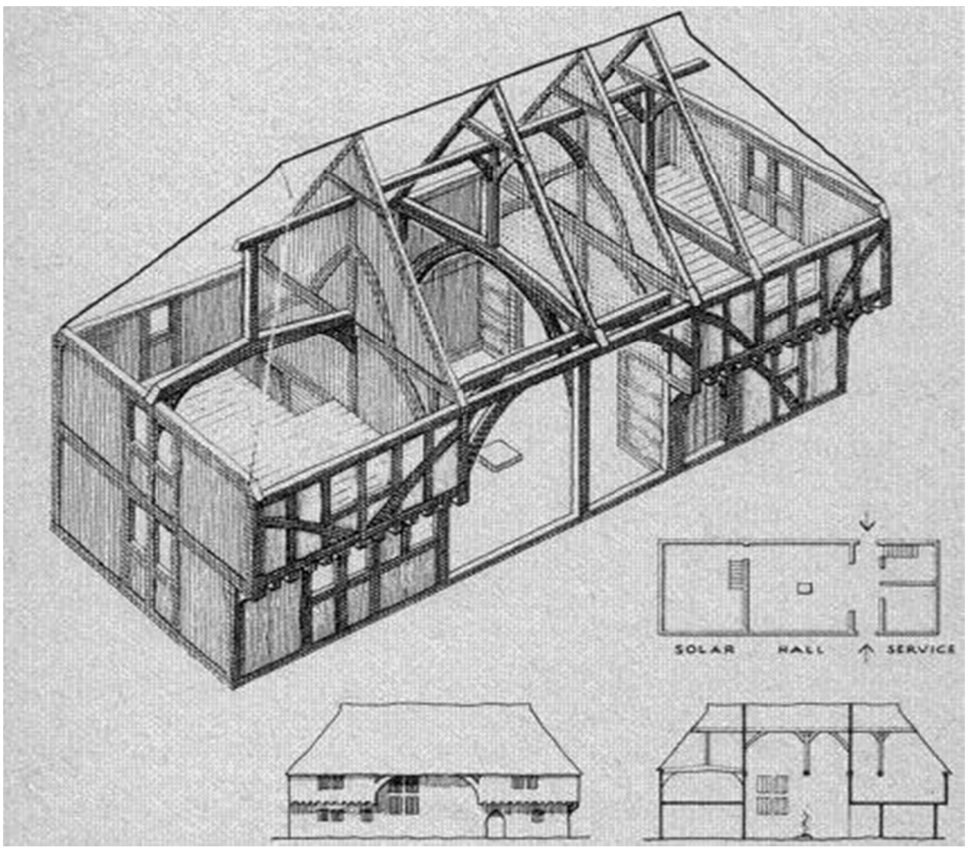


Figure 3.11: An example of a medieval house with a common layout from Fordham, Essex http://www.camulos.com/fordham/shoulder.htm

Houses in London could be large properties with multiple rooms owned by wealthy individuals, multi-storey townhouses, anywhere from three to four storeys tall, which sat above shops, workshops, or pubs were also common (Lilley 2002; Schofield and Vince 2003).

Few of the houses inhabited by the low status population have been recovered (Lilley 2002; Schofield and Vince 2003). These were made of organic materials, such as wood and thatch and typically lined the streets, which have since been widened. As a result, the remains of these buildings rarely survive in the archaeological record (Lilley 2002; Schofield and Vince 2003).

3.2.5 Post Medieval Period

Figure 3.12: "The White house" in Chelsea, built 1877
http://hoocher.com/James_Mc_Neill_Whistler/James_Mc_Neill_Whistler.htm

Towards the end of the Late Medieval Period and into the Post Medieval Period, which extends from the 16th century, the population living in cities had grown considerably. This increased population density made the likelihood of fire spreading from house to house more likely, and in Southeast England, the area covered by this study, during this period laws had to be enacted to regulate the types of building materials being used (Brimblecombe 1987). Only non-flammable materials such as stone, brick, slate and tiles could be used (see Figures 3.12, 3.13 and 3.14), and there were attempts to improve the ventilation in buildings made of these materials. For example, curved tiles have been found interspersed throughout the roof tiles to allow air from the house to escape beneath them (Johnson 1993). As in the previous periods, low status housing would be of poorer quality, in less desirable areas of the city, and have fewer amenities (Olsen 1999) (see Figure 3.15). Poor populations would be limited to areas close to their source of income and as the demand for these locations would be high the lower status groups would be limited to single rooms, often shared with family or other tenants (Sutcliffe 2006; Wohl 2002). In rural environments low status individuals would live in small cottages that were also little more than one room with few amenities (Sutcliffe 2006; Wohl 2002).

Figure 3.13: 18th house from London

As access to wood became more limited, the population was required to use more common, and thus cheaper, alternative fuels. By comparison to wood, coal was considered an unattractive fuel, because the smoke produced was acrid and it would have altered the taste of food cooked over it (Brimblecombe 1987). However, by the Post Medieval Period, coal was adopted almost universally, even by the upper classes, which used the relatively cleaner Scottish coal (Brimblecombe 1987). The almost universal use of coal in Britain in the Post Medieval Period instigated the installation of chimneys in most homes to remove the foul smelling smoke (Brimblecombe 1987). However, the smoke from the many households within a small area, combined with smoke from other activities carried out nearby, would have remained in the atmosphere and the population exposed to it everywhere, including outside the home. This likely affected the health of the population to some extent in spite of the chimneys. Historical documentation about the external environment from this period describes the extent of the pollution. While these might be biased, for example if they were written in support of laws attempting to clean the air, they are consistently corroborated by personal accounts (Brimblecombe 1987).

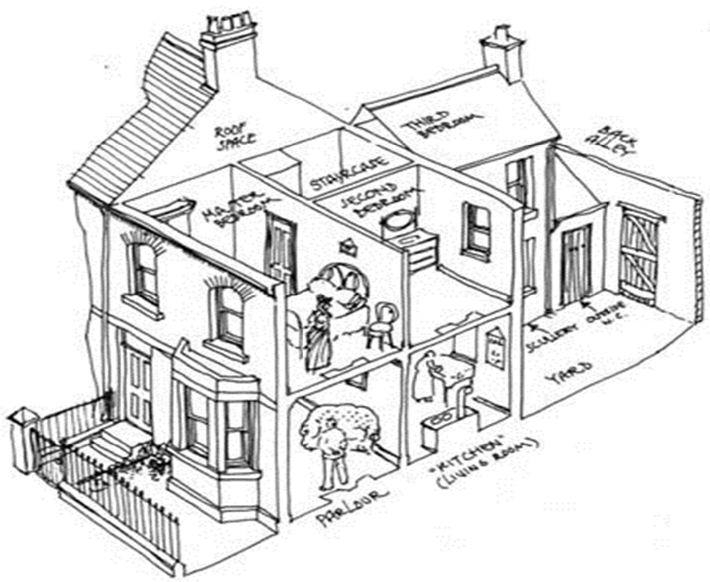


Figure 3.14: Layout of a typical terraced house dating from the late nineteenth century http://hassoozturk.seesaa.net/article/142316571.html

In spite of the obvious advantages of having chimneys to remove smoke, there were many people who mourned the loss of smoky homes (Brimblecombe 1987). As described in the previous section, the advantages of smoke for hygiene and food preservation were well known. In some homes, openings were built into the chimney so, when opened, smoke would fill the chosen room (Johnson 1993). In Suffolk, in short stack houses, which were originally built with chimneys, nonetheless, show extensive smoke staining on the interior of the roof (Aitkens 2009). The chimney is believed to have intentionally been built too short to reach the roof of the house and, as a result the smoke from the living areas of the house would rise up the chimney and disperse into the loft space before escaping through other features, such as gablets (Aitkens 2009). This might have allowed the household to dry and preserve organic materials in this smoky area. Similar features have been found in houses in Yorkshire, which could suggest this was a more widespread feature than previously assumed (Johnson 1993).

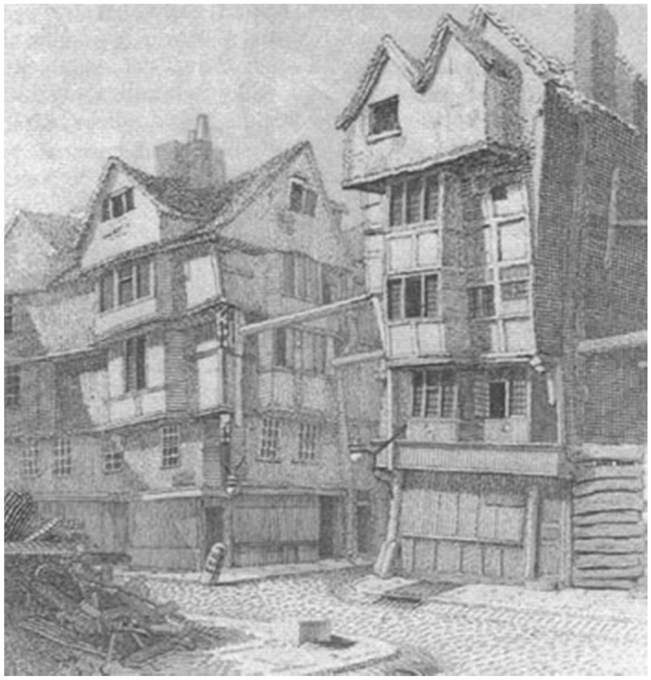


Figure 3.15: Low status housing on Butchers row, London. 1798 (Olsen 1999)

3.3 Occupation and respiratory disease

The home is not the only place where people spend significant amounts of time. Regardless of culture, subsistence activities are a significant time commitment. In living populations, certain occupations that expose workers to high concentrations of pollutants on a daily basis are known to be significant contributors to respiratory disease (Bruce *et al*. 2002; Ige and Awoyemi 2002; Lane 1958; World Health Organisation 2006), in particular, occupations that expose an individual to relatively high concentrations of particulates in the air of whatever cause. As mentioned in Section 2.1.1, these occupations can range from those where individuals are in close contact with smoke from fires, such as baking or smithing, to any occupation where there would be abnormally high concentrations of particulates in the air, such as mining (Bruce *et al*. 2002).

Since this study covers almost three millennia, the amount of information regarding occupation differs significantly between early prehistoric populations (few written records) and the latest post medieval populations, for which there is a considerable written record.

Furthermore, prior to the migration of individuals into cities, specialisation (performing one type of activity throughout life) rather than performing the same activities for their own household or community as needed, was rare.

In early populations whose economies were mainly based on agriculture, day to day activities would have varied throughout the day, week, month and year. This varied activity could be less likely to cause irritation to the respiratory system than daily activities such as metalwork or mining (World Health Organisation 2006).

In the Iron Age, there is some evidence of specialisation in the production of items that were widely distributed and items that were made for the very high status individuals. However, very few individuals are likely to have specialised in any one activity or type of craft production (Bradley 2007; Haselgrove 1999). Activities such as pottery, metalworking, mining and salt production would have been carried out by most of the population for their own household around their normal agricultural activities (Bradley 2007; Haselgrove 1999). It is possible that work that required more expertise, such as iron-smithing, could have been performed by specialists who travelled to individual communities, all of which have some evidence of iron work (Haselgrove 1999). However, this is just speculation.

As in the Iron Age, in the Roman Period, agriculture remained the most common industry (Cleary 2006). However, some artisans, such as potters, were still able to compete with goods imported from the continent. Metalworking, and thus mining, was also an important industry during this period (Cleary 2006). Nevertheless, unlike in the Iron Age, where the population carried out many of the craft making activities for themselves, in the Roman Period the population in Southeast England frequently imported goods from the continent, such as pottery (Haselgrove 2006). However, the development of cities and infrastructure in England during the period would have provided specialised work, such as building, baking, metal work, leather work, pottery, and other such activities which could have exposed the individuals carrying them out to higher than average concentrations of air pollution (Cleary 2006).

There is little evidence of specialisation in specific forms of craft production from the Early Medieval Period with the exception of some status goods. Given this it is unlikely that a significant proportion of the population specialised in some form of craft production. As in the

Iron Age, activities that would have exposed the manufacturer to high levels of smoke, such as metalwork and pottery appear to be widespread and small scale. However, there is still evidence for trade with the continent (Hills 2006). Areas of Suffolk and Essex, near the sites of Edix Hill and Staunch Meadow, as well as in the west near the site of Cannington, were well known centres of iron working in previous periods and it is possible that these activities continued into this period. However, excavations of settlements, but not areas outside of settlements, could mean the evidence has not yet been found for iron working (Carr *et al*. 1988; Malim and Hines 1998; Rahtz *et al*. 2000). Unfortunately, without evidence it is difficult to say what effect, if any, this sort of craft production would have had on the individuals examined in this study.

Work in the Late Medieval Period, particularly for the poor, would have differed significantly before and after the plague epidemics that occurred at this time (Dyer 2000). Prior to the plagues, with such a large population, most of the rural population were feudal dependent peasants. However, following the plagues the much smaller population available meant that the demand for labourers outstripped supply, and allowed poorer segments of society to choose their work as well as live on a more comfortable wage. Both men and women would have been involved in agricultural work, although they would have performed different activities, such as food processing and spinning (Dyer 2000; Lilley 2002). Historical documentation suggests that, in the Southeast, rural populations were predominantly involved in agriculture, with fewer people working in trades such as building and craft specialisation (Dyer 2000). Many of the peasants during this period, even those who owned small areas of land, earned cash through selling surplus foodstuffs or engaging in wage-earning labour at less busy times of year. At least one third of the population of Late Medieval England gained all or part of their livelihood by earning a salary (Dyer 2000). From the 14^{th} century when the population decreased as a result of epidemic infection, labourers were more in demand and could earn higher wages for short term work which could be carried out in free time while also allowing them more leisure time (Dyer 2000). Women also were involved in wage earning, particularly in trades involving food and drink, or areas such as spinning and weaving (Dyer 2000). In addition to specialisation being necessary, where the population had little access to land for subsistence, towns enabled many artisans in a small area to share resources, as well as allowing easy access to consumers of their products (Dyer 2000; Lilley 2002). However, some activities would not have been desirable in towns. Any activities that required a large amount of resources, such as wood, would profit from being located closer to these sources. Furthermore, the relative closely spaced wooden buildings that made up the cities meant that a small fire could quickly destroy many homes. For this reason activities which required fires, such as a kiln for firing pottery, were preferably placed in the countryside (Dyer 2002; Lilley 2002).

In the Post Medieval Period, the concentration of smoke in a smaller, more population dense, area would be evident and it has been noted in a great deal of historical documentation (Brimblecombe 1987; Ross 2008). The proximity to commercial and industrial spaces would add to the already high levels of domestic air pollution. Lime production in particular has been blamed for the high levels of pollution in London, particularly in the summer when domestically produced pollution caused by heating would be at its lowest, but lime production increased as a result of construction work (Brimblecombe 1987; Ross 2008). In addition to lime production, any trade, such as brick making, metal working and baking, which use heat in the form of kilns, furnaces, or ovens, would have added to the concentration of smoke (Brimblecombe 1987; Ross 2008). In some cases these workshops would be close to or in the same building as those in which the people lived (Dyer 1998; Schofield and Vince 2003).

Although craft production would have been more conveniently located in the countryside where raw materials were closer, property values would have been lower, and lower population density would mean fewer people were affected by any unhealthy by-products of manufacturing, towns remained attractive locations. The towns contained large populations of consumers to buy goods and had better access to trade routes and merchants. However, high rents in towns could force some craftsmen to work in areas with lower property values, usually further from the town centre, or outside of the town completely (Schofield and Vince 2003). In order to benefit from shared resources, some industrial activities took place in specific districts. Of these, some, including founding, tanning and timberwork, were located just outside the city centre, providing more space to carry them out and store materials. The poorer populations who typically lived in these areas would have been exposed to the higher levels of air pollution created (Schofield and Vince 2003).

Occupations would have differed along gender lines through most of these time periods, as they do in much of the developing world today, and it is likely that women of all status groups spent more time indoors, although not necessarily for the same reasons. Women in rural environments would have aided with agricultural work, but due to the requirements of child bearing, likely spent more time indoors. Women in higher status groups would also likely be kept indoors more than their male counterparts as a result of cultural and religious traditions (Fleming 2001).

3.4 Climate and its impact on respiratory disease

As described in section 2.1.2, the upper respiratory system needs to be kept within a very narrow range of temperatures and humidity in order to function correctly. The environment is kept ideal by the respiratory system, because it warms and moistens the air as it is inhaled (Jones 2001). However, when the weather is outside a tolerable level it becomes too difficult for the respiratory system to compensate sufficiently, and when this happens, the risk of respiratory disease goes up (Ayres *et al*. 2009). In addition to directly affecting the functioning of the respiratory system, changes in climate can also change the types and concentrations of particulates in the air, affecting the prevalence of respiratory disease indirectly. Clinical research suggests that there is a link between warm temperatures and respiratory disease caused by air pollution in the atmosphere, although this could be due to more time spent outdoors in warm weather (Ayres *et al*. 2009). Even small increases in temperature can alter the types of vegetation that grow and the concentration of particulates such as pollen and dust in the air. Environments that are more humid are also more likely to increase the concentration of fungi and mould spores, which can also lead to higher prevalence of respiratory disease. Furthermore, climate can significantly affect the ability of a building to ventilate. In air quality tests conducted in a reconstruction of an Iron Age building in Lejre, Denmark, humid conditions and low winds were found to lead to significantly less smoke escaping the domestic environment, while windy conditions significantly increased ventilation (Beck 2007). Relatively rapid climate change can also increase the risk of allergic reactions. As temperature rises or falls, new vegetation may be able to thrive in new environments. This can expose the population to new particulates in the air. As the individual will not have encountered this particulate, or perhaps not in large quantities, the immune system will not be able to deal with it (Ayres *et al*. 2009).

Climate can be assessed on a large scale through the analysis of ice cores from glaciers by examining trapped gases and pollen in the core. On a smaller scale, the appearance or disappearance of flora and fauna that are adapted to only very specific environments can signal changes in the environment in a particular area. Where historical records exist, indirect evidence of crop types, when they were harvested, and how many individuals had to be employed for the harvest, can indirectly signal annual changes in temperature and precipitation (Alverson *et al*. 2003; Cowie 2007; Cronin 2009). Given the different amounts of information on climate available for the time span of this research, the most accurate relative annual temperature information for Southeast England will be given. In some cases this may be specific to the area in which the populations examined lived, but in other cases this could be for Western Europe in general.

Throughout the Iron Age there was a decrease in average temperature from the previous period until approximately 400 BC when the temperature rose (Haselgrove 2006). This is evidenced by the movement of the population to previously abandoned highlands and the exploitation of new soils resulted in the intensification of new types of crops grown (Haselgrove 2006). During the temperature decline the climate also became increasingly wet (Bell 1996), which would have led to increased concentrations of mould and fungi in the air. This could have led to a higher rate of allergic reactions, and by extension evidence of inflammation in the maxillary sinuses (Ayres *et al* 2009).

Pollen and historical evidence demonstrate that the average annual temperature rose in the Late Iron Age and throughout the Roman Period by approximately 2°C (Dark and Dark 1997; Jones 1998). The populations that lived in the warmer drier climate from the fifth century BC well into the Roman Period would have been exposed to fewer of these particulates. However, as the climate changed, new vegetation could have exploited new regions it could not previously. Exposure to new pollens could also have increased the risk of allergic reactions in the populations who lived while these climate changes were occurring. By the fifth century AD, the end of the period, the average annual temperature fell again by approximately 1.5°C and the climate was relatively wet compared to the Roman Period (Dark 2000; Jones 1998). As in the Iron Age, this could have led to an increased likelihood of allergic chronic maxillary sinusitis, and the population might also have spent relatively more time exposed to smoke and dust indoors (Ayres 2009).

By the end of the Early Medieval Period, in the AD 11th century, the average annual temperature rose again (Lamb 1995). However, the temperature began to fall in the late 12th century beginning what is commonly referred to as the "Little Ice Age", a period of relative cold lasting through the Post Medieval Period (Alverson *et al*. 2003; Cowie 2007; Cronin 2009). The annual average temperature began to fall significantly from the 14th century in spite of having begun the period with the highest temperature of the period covered by this study (Alverson *et al*. 2003; Cowie 2007; Cronin 2009). These climate changes are documented historically, particularly in relation to agriculture and the impact on food production (Alverson *et al*. 2003; Cowie 2007; Cronin 2009). This climate change affected agriculture so dramatically that it is in part responsible for the movement of the population out of the countryside into the cities (Dyer 1998). Approximately at the end of the Late Medieval Period, there was a short rise in annual temperature before the average temperature fell again in the sixteenth century. This variable climate during this period makes it difficult to interpret the relationship between respiratory disease and climate during this period unless a cemetery was only in use for a short and known time. It is clear from historical records that most of the Post Medieval Period was relatively cold and wet. In the18th and 19th centuries, there was a slight rise in average temperature but this reflected the relatively hot summers in contrast to the cold wet winters (Alverson *et al*. 2003; Brimblecombe 1987; Cowie 2007; Cronin 2009; Lamb 1981).

3.5 Summary

Based on the information discussed in this chapter, it is possible to estimate which populations would have been exposed to relatively high and low concentrations of air pollution, and which populations were at greatest risk of respiratory disease. Both rural and urban populations were likely to have been exposed to pollution in the home and atmosphere although the relatively high population density in urban environments could have led to particularly high concentrations of pollutants in the air. Furthermore, the population living in urban environments were more likely to specialise in a specific repetitive activity or service. If a significant proportion of these individuals performed daily tasks that required them to inhale poor air quality, this could also lead to a higher prevalence of respiratory disease in these populations. Finally, the climate at any given time may have led to increases or decreases in respiratory disease depending on how it affected vegetation, lifestyle, ventilation of buildings, and the respiratory system itself. This will be discussed further in Section 6.6. If the hypothesis that populations exposed to poor air quality more frequently are more likely to develop respiratory disease, is correct, then the populations expected to have the highest prevalence rates of chronic respiratory disease should have correspondingly high prevalence rates of lesions in their sinuses and on the visceral surfaces of their ribs. In the next chapter, the 12 populations from Southern England being used to test this hypothesis are described and discussed, as well as a detailed description and discussion of the methods used in this study

4 Materials and Methods

The previous chapters have been focused on background information in order to provide a better understanding of the conditions and lesions discussed here as well as the history of the populations and the region discussed in this study. In this chapter, the specific materials and methods used in this study will be discussed in detail. The materials will be discussed in Section 4.1 and methods will be discussed in Section 4.2.

4.1 Materials

4.1.1 Introduction

This section will discuss the twelve skeletal samples chosen for this study. The first section discusses the method for choosing the populations examined. Ideal samples were described and then populations were chosen on the basis of being available for study and for most closely resembling the ideal samples. The following sections will specifically discuss the populations chosen for these samples, focusing on lifestyle and environmental factors that may have impacted exposure to poor air quality, as well as factors which may have affected their preservation post mortem. In particular, the design of buildings, building materials, subsistence methods, population density, occupation, types of fuel used, and methods for their use are among the most important factors discussed here. Funerary rites and circumstances of excavation are also described in order to determine whether these affected the demographic makeup of the preserved populations.

4.1.1.1 Skeletal samples selection

This study attempts to determine the possible causes of chronic maxillary sinusitis and rib periostitis noted in the bioarchaeological and clinical literature discussed in the previous chapters, whether it is possible to highlight the most likely aetiology of these conditions in the past and, if possible, be certain of the aetiology of the lesions in a given individual. In order to determine whether certain environmental and lifestyle factors result in significantly higher or lower prevalence rates for chronic maxillary sinusitis or rib periostitis, these factors needed to be contrasted wherever possible. Furthermore, in order to eliminate confounding factors, such as climate, only populations from a relatively small region should be examined.

It has been suggested in previous bioarchaeological studies that social status, indirectly by way of factors such as occupation and the domestic environment, may be causing difference in the prevalence of these two conditions (Roberts 2007). In order to determine if there is any effect caused by status, samples defined as either high or low social status were examined wherever possible. These terms are unfortunately used relatively in this study, as contemporaneous views and definitions of status change considerably over time. In the Late and Post Medieval Periods, the two periods where social status is contrasted between two skeletal samples, high status has been defined as individuals having been buried in such a way or location as to show the population was relatively wealthy, or were buried by people with enough wealth to afford such a rite. These individuals would likely have been wealthy enough to afford access to better house building materials and cleaner fuels, and have carried out 'cleaner' occupations or daily activities that would all result in less exposure to air pollutants (Akunne *et al*. 2006). By contrast, low status individuals would have been more likely to have less healthy living environments, with more densely populated housing, and heated or lit with whatever fuel was affordable. These individuals may have worked in trades, such as founding, baking, or leather producing, which kept them in close contact with air pollutants throughout the day, even outside the home (Ige and Awoyemi 2002).

Unfortunately, the ideal examples of a particular social stratum are not necessarily available in the bioarchaeological record, or distinguishable from the rest of the population. Often, very little is known of the life of a particular individual or status and this must be inferred from their funerary rights, including the type of grave goods or type and location of the burial, or extrapolated from the knowledge of nearby archaeological sites that most likely contributed part or all of their living population to the nearby cemetery population. There are undoubtedly individuals within the cemetery populations studied here who were not representative of the group to which they have been assigned. Some individuals may have spent their life in another environment and migrated late in their life, or may have been buried far away from where they lived due to a position they held or a relationship to a particular group (Barber and Bowsher 2000). Similarly, money and status can be gained and lost. It is possible the individuals being examined rose in society or lost status late in their lives. There is one known example from the crypt at St. Bride's Church where coffin plates were found associated with the human remains. Historical records document one individual who spent many years prior to his death in prison before being interred in the crypt by his wealthy family (Scheuer and Black 1995). His lifestyle prior to his death does not make him an ideal candidate as an example of someone of high social status. The hope is that these individuals, if they were in the samples in this study, are the minority and do not significantly confound the results.

Environment has also been suggested to be a responsible for affecting the prevalence of lesions associated with upper and lower respiratory disease. In particular, urban and rural environments are thought to cause different rates of respiratory disease due to differences in the amount and concentration of pollutants in the air (Lewis *et al.* 1995; Roberts 2007). Urban and rural populations are contrasted in the Late and Post Medieval Periods, and to some extent the Roman Period. The definitions of urban and rural, again, depend on the period being studied. The urban environments in this instance are defined by their relatively high population density by comparison to the rural environments. This is how these environments are defined in modern terms. However, overall population density would be lower in the past than in living populations. Low population density in a rural environment would be a necessity for a population who engaged almost exclusively in agriculture and, as a result, required a large amount of land for cultivation. By contrast, the population in an urban environment who had little land available would have had to specialise in some area of trade or craft production in order to afford the goods necessary for subsistence if they did not have another source of wealth, such as an inheritance. It is expected that the difference in subsistence methods, in addition to the differences in population density, would affect the overall concentration of atmospheric pollution to which a person would be exposed and, as a result, potentially be a reason for any difference in the prevalence of respiratory disease.

Ideally, there would be notably high and low status populations in separate cemeteries as well as populations that are truly urban and rural, also buried separately for every period of time investigated in this study. However, in reality this was not the case. In the Iron Age there were no urban populations and no skeletal populations large enough for statistical analysis that clearly represented a higher status group. Given the small number of excavated burials from this period in this region, it was not possible to make any comparison of the prevalence of respiratory disease within contemporaneous populations. In the Roman Period, few large burial grounds associated with truly rural populations have been excavated. As a result two populations associated with towns were analysed, Lankhills, Hampshire and London. However, given the relative size of London in the period, it is treated as relatively urban compared to Lankhills, although neither population is thought to have a population density as high as the urban populations in the Late and Post Medieval Periods (Millet 1995; Berber and Bowsher 2000; Dyer 1998). These cemeteries may also have included individuals who lived in rural contexts before being buried outside the Roman cities (Barber and Bowsher 2000). In the Early Medieval Period there were no urban populations or significantly high status cemeteries with a large enough sample for statistical analysis. Under these circumstances a population from further west, Cannington in Somerset, than the other populations in this study was chosen for comparison to a sample made up of two populations from within Southeast England, Staunch Meadow, Brandon, Suffolk and Edix Hill, Cambridgeshire. While this does not allow for a contrast in subsistence to be made, the different environments, climate and occupations in these different parts of the country could be expected to lead to significantly different prevalence rates for respiratory disease (Roberts 2007). It is only in the Late Medieval Period that rural, urban, high and low status skeletal populations were all available for study. Unfortunately what populations were available to examine were not the extreme ends to the range of social status groups or environments, and therefore they were not ideal to contrast these lifestyle differences. The cemetery at the town of Abingdon, Oxfordshire dated from the twelfth century and would have comprised individuals from the town but also from the surrounding area (Wakely *et al*. 1998). It is for this reason that this population is relatively rural compared to the two urban samples from central London, St. Mary Graces and a sample made up of cemetery populations from St. Nicholas Shambles and Guildhall Yard East. These two urban populations also do not represent the strongest possible contrast. Preferentially, the low status population would be made up of a population living on the edge of the city where the cost of living was lowest and conditions were the poorest. However, no such populations were available for study. The high status population was also not solely made up of high status individuals. In the Post Medieval Period, there were no truly rural populations available from the same area as the urban populations, and therefore a population from just outside London, Chelsea Old Church, was chosen as a contrast to the two populations from central London, St. Bride's Crypt and St. Bride's Lower.

4.1.1.2 Sample size

Unfortunately, the thin and fragile bone of the maxilla and ribs, particularly with their position at the anterior of the body, closest to the surface when the individual is buried supine, have a lower likelihood of survival in the burial environment than other more robust or posterior bones (Henderson 1987; Waldron 1987). Poor burial environment and other external factors also result in poorer preservation (Henderson 1987). The cemetery populations from which the samples in this study were taken had to be very large to ensure that a sufficient number of individuals with these elements would be available to be recorded. Where there was no one sufficiently large population from the region being studied, populations with similar lifestyles and geographical locations were combined, where possible, to create a comparable sample size. There was only one instance where this was not possible. In the case of the low status sample from Late Medieval London, only two skeletal populations, St. Nicholas Shambles and Guildhall Yard East, totalling over 150 individuals, were available for study, but only 40 individuals had recordable sinuses and ribs. No other comparable populations were available to increase the size of this sample. This is in a stark contrast to the largest sample examined, Abingdon Vineyard, dated to the same period, which had over 150 individuals who had sinuses and ribs preserved. There were two other combined samples. The small number of burials recovered from the Iron Age in this region made it necessary to combine seven cemetery populations from different parts of Southeast England (Danebury, Folly Lane, Micheldever Wood, Mill Hill, Suddern Farm, Winnall Down, and Yarnton). In the Early Medieval Period two rural populations from Cambridgeshire (Edix Hill) and Suffolk (Staunch Meadow) were combined.

4.1.1.3 Location

In order to limit the effect of climate and geography as a confounding factor in this study, the samples were chosen on the basis of being located in a relatively small region, in this case the Southeast (see Figure 4.1). There was only one sample, Cannington, which fell outside of this region. As discussed above, it was chosen as a deliberate contrast of geography for the Early Medieval Period, which is discussed in more detail below. Southeast England was chosen as the region of study because it has not only been continuously occupied from the Iron Age, but because the extensive development in the region in recent times has meant a great deal of excavation, and consequently a larger number of available collections of human remains from

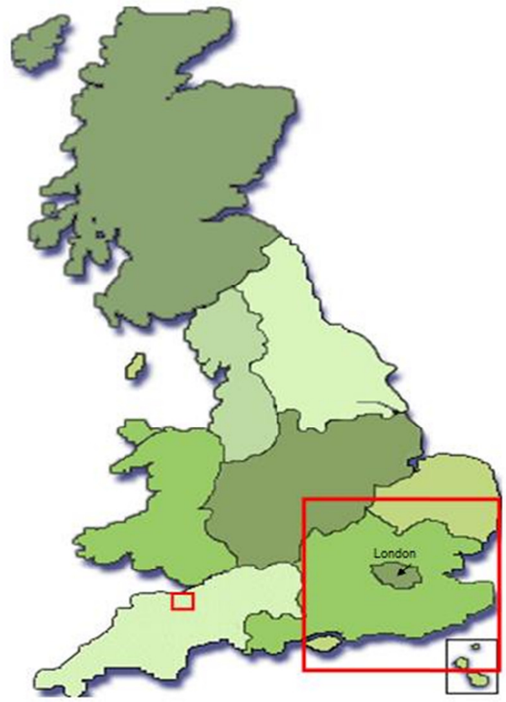


Figure 4.1: Modern map of England. The area of study is surrounded by the large red square while the location of Cannington, the only population excavated from outside the area of study is indicated by the small red square.

all of the periods being studied here. More skeletal populations available for study in the region increased the possibility of finding one that fit the specified criteria necessary for the samples in this study. As was discussed above, it is, however, a fact of this type of research that no matter how much material is available for study, finding the ideal material is not always straightforward or even possible.

4.1.1.4 Date

English history and prehistory is divided into periods of time of varying length defined by significant cultural changes. In order to examine a small range of climate and cultural change, as well as compare these results to as many of the previously recorded populations, it was decided that these time periods would be used to categorise the populations so they could be compared contemporaneously as well as through time. The availability of prehistoric human remains decreases as the remains get older. The Iron Age was chosen to be the earliest time period examined here and even in this period human remains were rare enough to require combining several populations.

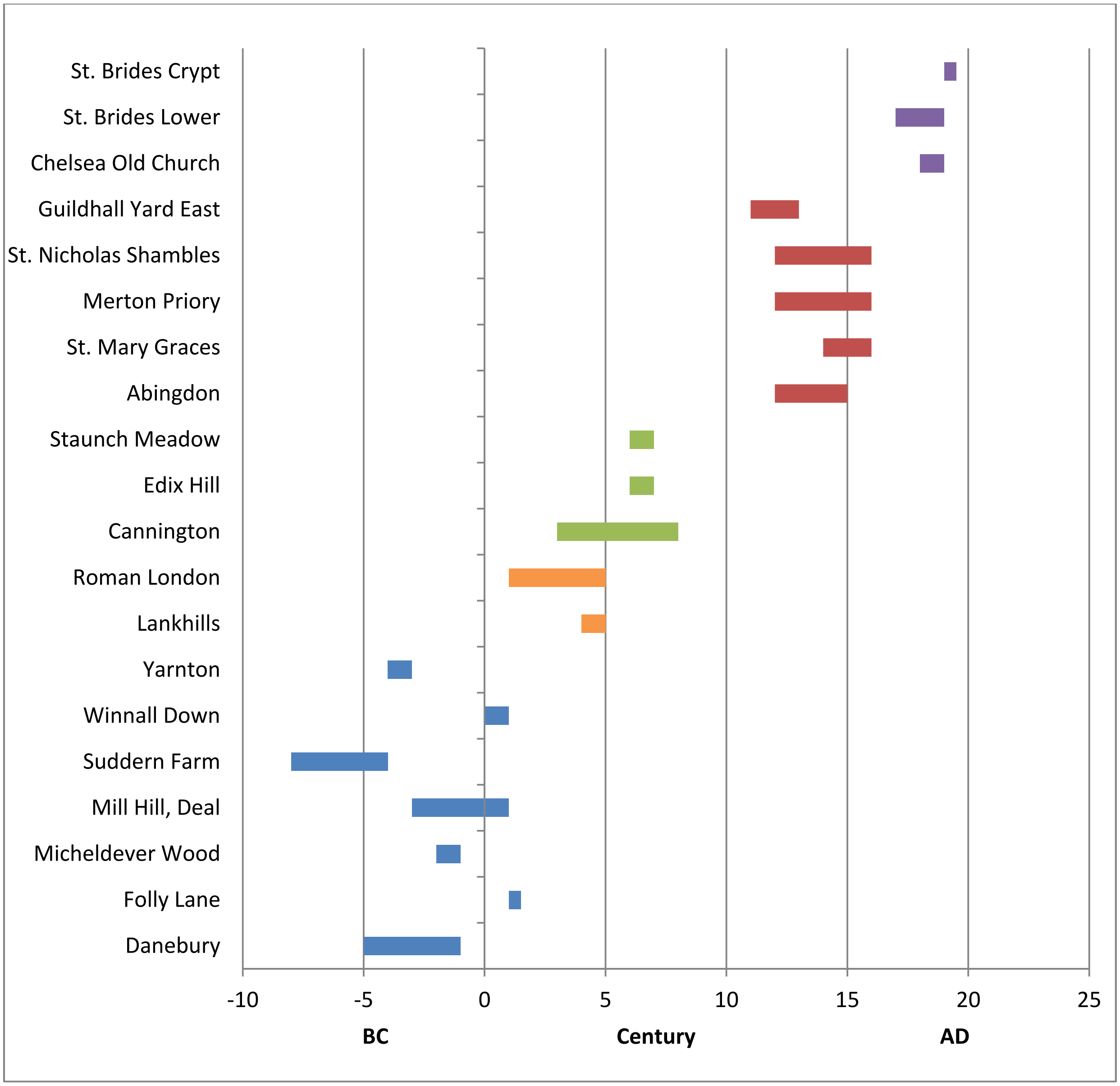


Figure 4.2: The duration of use of each of the cemeteries, based on archaeological and historical data. The sites assigned to the Iron Age are shown in Blue, the Roman sites in Orange, the Early Medieval sites in green, the Late Medieval sites in red, and the Post Medieval sites in purple.

In all of the five periods chosen for study, the Iron Age (8th century BC to AD 1st century), Roman Period (AD 1st century to AD 5th century), Early Medieval Period (AD 5th century to AD 12th century), Late Medieval Period (AD 12th century to AD 16th century), and Post Medieval Period (AD 16th century to AD 19th century) , populations were chosen preferentially for fitting well within a time period and not overlapping the populations from the preceding or proceeding time periods. However, this is not always the case (see Figure 4.2). In the cases where the use of a burial ground extended into another period the vast majority of the period of use had to be in the period it was assigned to, limiting any confounding factors.

4.1.1.5 Age at death

It has been noted in previous literature that the formation and eruption of the maxillary dentition can lead to pitting in the maxillary sinuses, which mimics that appearance of sinusitis (Lewis *et al* 1995). In order to limit the confounding effects of this, it was decided that only adults, as defined by the possession of a full and completely erupted set of maxillary dentition, would be examined and recorded.

4.1.1 Skeletal Samples

4.1.1.6 Iron Age

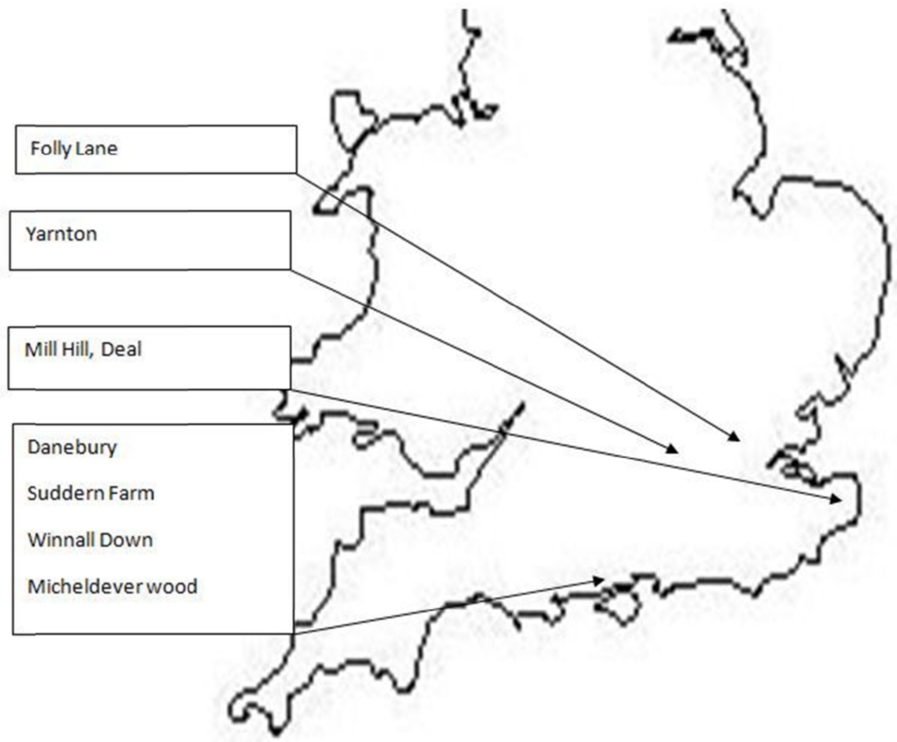


Figure 4.3: Location map of Iron Age sites used in this sample

The Iron Age in England dates between the eighth century BC and the first century AD (Haselgrove 2006). The ideal sample would have been from a population with at least 100 individuals with sinuses and rib preserved, who are known to have lived in the same environment and have had the same lifestyle. However, due to the age of the remains from this period, combined with the seeming rarity of burial as a funerary right, human remains from this period are scarce (Whimster 1981). This means that the skeletal populations available to be studied are typically small compared to later periods and unevenly distributed geographically, depending on where excavations have taken place and whether the local environmental conditions are better for preservation (Henderson 1987). This made it impossible to find a single population from this region in this period that would provide a large enough sample of individuals with sinuses and ribs preserved for statistical analysis and comparison to the later periods examined in this study. As mentioned above, this made it necessary to combine several small cemetery populations in order to create a sample size sufficient for statistically significant results.

However, even with a sufficient sample size, given the lack of information about burial practice in this period, it is possible that the individuals recovered in these burial grounds are not representative of the living populations in this region at this time. If, for example, these individuals, as a result of differences in lifestyle or as a result of suffering from a particular disease, were buried rather than given the more common funerary rites of the period, this may significantly affect the interpretation of the data. The sites used are listed and discussed below, and their locations are shown in Figure 4.3.

4.1.1.6.1 Danebury

Original osteological Analysis	Hooper 1984
Location (county)	Hampshire
Date of use	5th to 1st C BC
Date of excavation	1969 to 1988
Environment	Rural
Status	N/A
Number of individuals excavated	70+
Numbers of individuals examined in this study	12
Curated by	Hampshire County Council Museums & Archives Service

Danebury hillfort was excavated from 1969 to 1988 in order to gain a better understanding of hillforts (Cunliffe 2003). The fort covered an area of 13 acres surrounded by ditches and ramparts. Excavations suggest that the site was inhabited between the fifth century BC to first century BC. It appears to have been burnt at the end of the fourth century BC and may have been unoccupied before being rebuilt around 270 BC. From this time, the occupation of the site became more intense. The population appears to have grown, while simultaneously all nearby rural sites became unoccupied, as though the entire rural population migrated to the fort (Cunliffe 2003).

The population of the hillfort has been estimated to be between 200 and 350 (Cunliffe 2003). It was likely a central place within the region. In addition to being well defended, it had granaries and ritual centres. Archaeological excavation found evidence of crafts and some high status artefacts such as beads and cauldron hooks, although there is nothing to suggest that the population was higher status than the other nearby communities (Cunliffe 2003). Agriculture would have been the predominant method of subsistence in this population (Cunliffe 2003).

4.1.1.6.2 Suddern Farm

Original osteological analysis	Hooper 2000
Location (county)	Hampshire
Date of use	BC 5th C to BC 1st C
Date of excavation	1991 to 1996
Environment	Rural
Status	N/A
Number of individuals excavated	Approximately 60
Numbers of individuals examined in this study	11
Curated	Hampshire County Council Museums & Archives Service

Suddern Farm was discovered by aerial photographs in 1976, 4.5km west of Danebury between Suddern Hill and Middle Wallop. It was excavated as part of the Danebury environs project in 1991 and again in 1996. It was a well defended medium sized site, surrounded by substantial enclosure ditches, which suggest this was a relatively high status population (Cunliffe and Poole 2000). The land would have been excellent for agriculture, being among the most arable in the region (Cunliffe and Poole 2000). Unfortunately, there was no material available to directly date the cemetery, but the site at Suddern Farm appears to have been in use from the seventh or eighth century BC to the fourth century AD. Based on the stratigraphic sequence and according to pottery finds it probably dates to between 500 and 250 BC, and based on all the evidence combined, is almost certainly dated to the early to middle Iron Age Cunliffe and Poole 2000).

The majority of the human remains associated with Suddern Farm were found in a small quarry developed outside the enclosure in the mid Iron Age. The few skeletons that were not buried in the quarry, two partial adult skeletons, some isolated bones, and one neonate, were found inside the enclosure. The quarry was initially excavated using a JCB, until human remains were discovered. This did cause some damage to the most shallowly buried remains (Cunliffe and Poole 2000). Only part of the quarry was excavated. The remains are estimated to represent approximately 31 adults aged more than 17 years old, nine children, and 20 infants (Cunliffe and Poole 2000). Approximately 15 of the skeletons were relatively complete. It has been estimated that if the remaining areas of the quarry contain a similar density of human material, the cemetery could contain 300 adults, 80 children, and 180 infants (Cunliffe and Poole 2000). The adults were buried in holes with no standardised size, just large enough to fit a flexed body. Later graves often cut through earlier ones. Infants were only found in the uppermost layer, which may be a result of the quarry becoming too full for any more adult burials, leaving only enough space to bury infants (Cunliffe and Poole 2000).

This cemetery is unusual when compared to the burials found in this region during this time (Cunliffe 2004; Cunliffe and Poole 2000; Parfitt 1995). At other Iron Age sites, burials have rarely been found to take place in the form of a burial ground. Burial on this scale also seems to be rare for this period in this region (Cunliffe and Poole 2000). In addition, it is not clear why this large Iron Age cemetery was created here, and filled completely, but no other nearby cemetery has been found; this suggests that no new burial ground was created to replace the one they had filled. It is possible that this form of funerary rite went out of fashion and another less visible rite took its place, or perhaps a new cemetery was developed elsewhere and has yet to be found (Cunliffe and Poole 2000).

4.1.1.6.3 Micheldever Wood

Original osteological analysis	Powell 1987
Location (county)	Hampshire
Date of use	BC 5^{th} C to BC 1^{st} C
Date of excavation	1975-1978
Environment	Rural
Status	N/A
Number of individuals excavated	14
Numbers of individuals examined in this study	2
Curated	Hampshire County Council Museums & Archives Service

Micheldever wood is a banjo enclosure, a semi-circular area of between 0.2 and 0.6 hectares approached by a long entranceway that resembles the shape of a banjo when viewed aerially. It is located near Danebury and Suddern farm in central Hampshire and was discovered during a survey prior to construction of the M3 motorway in 1973 (Fasham 1987). The site was mainly occupied from the second century BC to the first century BC (Fasham 1987). Excavations carried out from 1975 to 1978 revealed earthworks that made up the banjo enclosure as well as 14 complete skeletons in the enclosure ditch and various pits. Of these human remains two were adults, and the remaining twelve were infants and juveniles. Both adults were buried in graves outside of the enclosure. This is likely due to a custom that only allowed children to be buried within settlements (Fasham 1987). The two adults were the only remains analysed in this study.

4.1.1.6.4 Winnall Down

Original osteological analysis	Powell and Bayley 1985
Location (county)	Hampshire
Date of use	BC 5th C to BC 1st C
Date of excavation	1976 to 1977
Environment	Rural
Status	N/A
Number of individuals excavated	32
Numbers of individuals examined in this study	2
Curated	Hampshire County Council Museums & Archives Service

The enclosure at Winnall Down, less than 2km north-east of Winchester was discovered by aerial photographs in 1974 and excavated in 1976 and 1977. The site was occupied from the late Bronze Age through the Iron Age and includes Roman enclosures dating from the second century AD (Fasham 1985). Approximately 32 individuals were recovered. Of these, six were adults and 25 children. In addition to burials, there was one cremation and 78 incidences of scattered bone (Fasham 1985). Several structures dated to this period appear to be living accommodation. There are large or ritual buildings to suggest the population was high status (Fasham 1985). Unfortunately, although several of the adults had been very well preserved, three adult skulls had gone missing in the intervening decades since their excavation and were not available for examination.

4.1.1.6.5 Folly Lane

Original osteological analysis	Mays and Steele 1999
Location (county)	Hampshire
Date of use	BC 5th C to BC 1st C
Date of excavation	
Environment	Rural
Status	N/A
Number of individuals excavated	7
Numbers of individuals examined in this study	3
Curated	St. Albans Museums

Folly Lane, located 0.5km from the Roman town of Verulamium, southwest of modern St. Albans, was inhabited sporadically from the first century BC through to light occupation in the Early Medieval Period. The most substantial occupation, during the first century AD, was an Iron Age oppidum called Verulamium (Niblett 1999). It contained evidence of domestic and ritual activities as well as 22 cremations and seven inhumation burials (Niblett 1999). The areas that have been excavated suggest this may have been a farmstead (Niblett 1999).

The funerary rituals varied, perhaps based on social status. There was evidence of one high status cremation, but there were also cut marks on some of the skulls, which could have resulted from peri-mortem defleshing (Niblett 1999).

4.1.1.6.6 Mill Hill, Deal

Original osteological analysis	Anderson, 1995
Location (county)	Hampshire
Date of use	BC 5th C to BC 1st C
Date of excavation	1984 and 1989
Environment	Rural
Status	N/A
Number of individuals excavated	38
Numbers of individuals examined in this study	14
Curated	Canterbury Archaeological Trust

The Iron Age burials from Mill Hill, Deal were predominantly excavated between 1984 and 1989 (Parfitt 1995). As the quarry had been in use in the 19th century, some of the burials, most likely cremation burials dating from first century BC, were lost (Parfitt 1995). Unlike most cemeteries from this period, inhumation is believed to have been the primary funerary rite at this site. The inhumations were found in two distinct cemeteries, with remains dated to between the third century BC and first century AD in the central cemetery, and the remains dated to between the second and first centuries BC in the southwest cemetery. There was no archaeological evidence to suggest why individuals were buried in one cemetery as opposed to the other (Parfitt 1995). In addition to the Iron Age individuals, the central cemetery also contained human remains from the Roman Period and perhaps one Saxon individual (Parfitt 1995).

The original report on the human remains concluded that this cemetery population had roughly equal numbers of males and females and that 31.6% of the population failed to reach adulthood. The average height of this population was slightly taller than other Iron Age samples (Anderson 1995). There was very little evidence of infection and nutritional deficiencies seen palaeopathologically. There was also almost no evidence of trauma. There was some evidence of joint degeneration, though this was concentrated primarily in the central cemetery, which could suggest these were individuals of lower social status. Dental health was poor overall. Anderson (1995) suggests, in the absence of carbohydrate rich foods which typically cause caries, that the population was likely chewing tough foods that fractured the teeth and subsequently led to the carious lesions. In addition to caries, there were also high levels of periodontal disease and dental abscesses (Anderson 1995).

4.1.1.6.7 Yarnton

Original osteological analysis	Hey *et al* 1999
Location (county)	Hampshire
Date of use	BC 5th C to BC 1st C
Date of excavation	1996
Environment	Rural
Status	N/A
Number of individuals excavated	46
Numbers of individuals examined in this study	13
Curated	Oxford Archaeology

Yarnton is located in the Upper Thames Valley, 8km north-west of Oxford on the north bank of the River Thames. It was one of many Iron Age settlements located in the region. The skeletal material was discovered during gravel extraction and excavated by Oxford Archaeology in 1996 (Hey *et al*. 1999). The archaeological material dated from the middle Iron Age to Early Medieval Period. Nine of the Iron Age skeletons were radiocarbon dated to between the 4th and 3rd centuries BC, although the site was not likely used for more than one or two generations (Hey *et al*. 1999). Using these dates and assuming, based on the demography, that the cemetery population was most likely representative of the living population that used the cemetery, the start and end dates of use were estimated using a Bayesian approach and Gibbs sampling (Hey *et al*. 1999).

The demography indicates that these burials probably represent a true cross-section of the population, but no neonatal skeletons were found (Hey *et al*. 1999). The cemetery appears to be a burial ground used by two or three families, a hypothesis which is supported by the three structures which appear to be houses found nearby (Hey *et al*. 1999). It is unclear why inhumation was almost exclusively used for only a short period of time, even though the site was inhabited throughout the Iron Age. It has been suggested that this may have been a temporary change of preference for burial, which was becoming more common in Britain from the middle Iron Age (Niblett 1999). It has also been suggested that these individuals may have needed to be disposed of quickly after dying from an acute infectious disease (Hey *et al*. 1999). There was no evidence of infection visible in the skeletal remains, but this could be a result of a short period of infection or lack of skeletal involvement. This explanation could explain the extremely similar radiocarbon dates attributed to the human remains that were analysed, as well as explaining why these individuals seemingly received a different funerary rite from the rest of the population in this region at this time (Hey *et al*. 1999).

4.1.1.7 Roman Period

The Roman Period, which extends from the first century AD to the beginning of the fifth century AD, experienced a great deal of cultural and political change. While much of the population continued to live as they had done before the Roman occupation, towns were also built as centres for administration, and both voluntary and involuntary migration from previously occupied Iron Age sites into larger town centres was common (Alcock 2006; Barber and Bowsher 2000).

In this period, the ideal samples would have been taken from a population who lived, one, exclusively in small villages and subsisted on agriculture, and the other one that lived exclusively in a town and subsisted mainly on food and products manufactured by and obtained from others. These samples would illuminate the effects of subsistence methods and environment. Individuals from the town environment would be expected to have been exposed to lower concentrations of air pollution than their counterparts, because these towns would have lower population densities and would not be centres for industry as they were in later periods (Sih 1999). The relatively urban population may have been exposed to fewer natural particulates, such as pollen and fungi that would be in higher concentrations when working with crops and livestock. Individuals who specialised in crafts or any other occupation that exposed them to smoke or other particulates in the air would be expected to have a higher likelihood of being affected than the remainder of the population (Ige and Awoyemi 2002). Unfortunately, populations associated with towns are the only populations available to study from this region during this period. In order to create a contrast London, a larger town is compared with Lankhills, a smaller town.

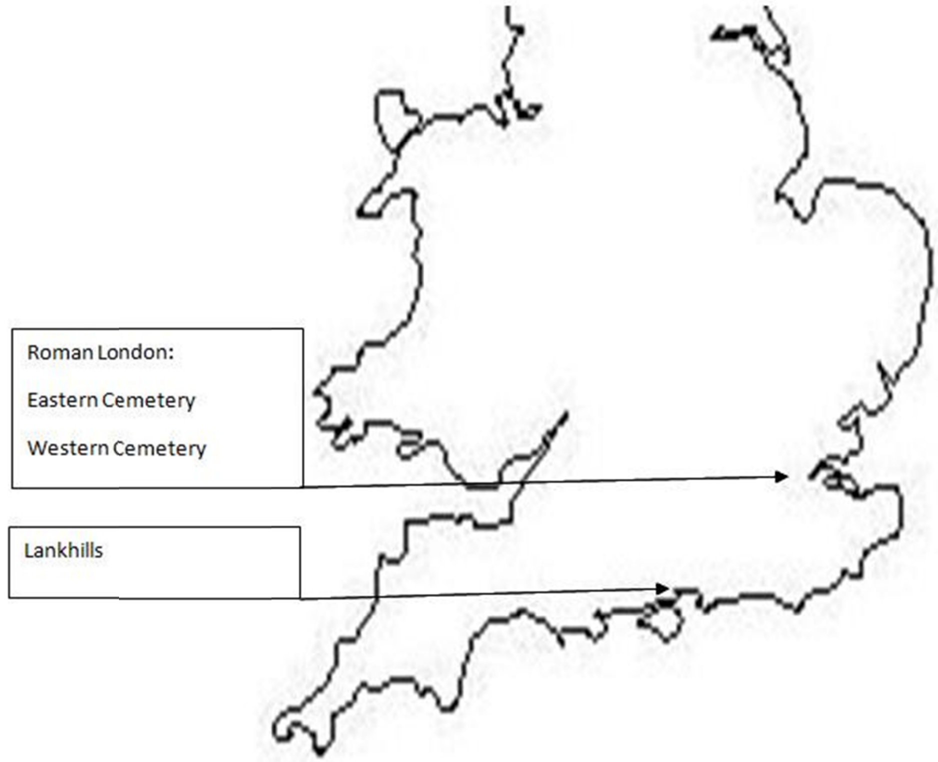


Figure 4.4: Location map of the Romano-British sites used in this study

4.1.1.7.1 Lankhills

Original osteological analysis	Clough, S.
Location (county)	Hampshire
Date of use	4^{th} C to 6^{th} C
Date of excavation	2000, 2003-2004
Environment	Rural
Status	N/A
Number of individuals excavated	284
Numbers of individuals examined in this study	74
Curated	Oxford Archaeology

The site of Lankhills, located 5km from the north gate of Winchester on a spur of land between the Itchen Valley in the east and the Fulflood valley in the south, was discovered during building work in 1961. Trenches were dug in 1967 uncovering closely spaced fourth century burials and excavations of the cemetery continued until 1972. Four hundred and fifty one Roman inhumations were excavated and only seven cremations. The long excavation was possible because the excavations were carried out by students at weekends as well as by professional archaeologists. These remains were not included in this study. The cemetery was excavated further from 2000 to 2004 by Oxford Archaeology and revealed 284 burials (A. Boyle pers comm). Coins in the burials combined with stratigraphy, date the earliest burials to later than AD 300, perhaps AD 310. No remains were found from after AD 500, and it is suggested that burials ceased around AD 410 (Clarke 1979). The area has been built over a number of times since it went out of use as a cemetery, resulting in damage to many of the remains (Clarke 1979).

4.1.1.7.2 Roman London

4.1.1.7.2.1 Eastern Cemetery

Original osteological report	Conheeny 2000
Location (county)	London
Date of use	1^{st} to 5^{th} C
Date of excavation	1983-1990
Environment	Semi-Urban
Status	N/A
Number of individuals excavated	550
Numbers of individuals examined in this study	69
Curated	Museum of London Centre for Bioarchaeology

The Eastern Roman Cemetery lay to the east of Roman London and covered an area of 12ha in the modern London borough of Tower Hamlets. It was in use between first and fifth century AD. A total of 550 inhumation burials were recovered from 12 excavations in this area.

Based on the types of burial, the population appears to be homogenous and individuals buried there probably lived locally (Barber and Bowsher 2000). It is difficult to tell what proportion of the inhumed population had immigrated into Britain. Since towns in the Roman Period would have been centres of administration, they would have housed military and administrative personnel who travelled to England from other parts of the empire, as well as individuals from other parts of England (Baber and Bowsher 2000). It is possible that some of the individuals buried here did not spend their life living in Roman London, but died and were subsequently buried there. It is also probable that not all individuals who lived locally would have been buried in the Eastern Cemetery. Several estimates of the population of London over the course of this period have been suggested based on the water supply and the waste disposal. They concluded that the population of London during this period was approximately 20,000 and undoubtedly fluctuated considerably over time (Barber and Bowsher 2000).

There was a relatively low proportion of females and infants found in the cemetery. It is unclear whether this is a result of burial practices, excavation bias, or a reflection of the real population demography. It is possible that the latter is true, because this urban centre would have housed many unmarried soldiers and officials (Barber and Bowsher 2000). If the former were true, researchers would expect to find a disproportionate number of females and juveniles buried, or disposed of using other methods such as cremation, or buried separately elsewhere (Barber and Bowsher 2000).

There is no clear evidence from the burials that would indicate the occupations of the population and there is no evidence that the population was particularly high or low status. Variations in health and grave goods which might be indicators of wealth and status were rare and occasionally conflicted. For example, one individual had pathological indicators of a poor diet, but high status grave goods (Barber and Bowsher 2000). Overall, this population buried in London had few lesions indicative of chronically poor health during their lifetimes. Fractures were well healed which suggests access to good medical care and the lack of metabolic disorders suggests that the population was overall adequately nourished. There was some possible evidence of tuberculosis noted in the original skeletal report (Barber and Bowsher 2000).

4.1.1.7.2.2 Western Cemetery

Original osteological analysis	Mikulski and Redfern 2009 Wellcome Osteological Research Database
Location (county)	London
Date of use	1st to 5th C
Date of excavation	Approx. 1980- present
Environment	Semi-Urban
Status	N/A
Number of individuals excavated	137
Numbers of individuals examined in this study	20
Curated	Museum of London Centre for Bioarchaeology

The Western Roman Cemetery, as suggested by its name, was located to the west of what was Roman London, within the current post code EC1, thought to have been arranged along the Roman road between London and Silchester (Mikulski and Redfern 2009). The material was excavated over a period of 30 years from several different locations as a result of excavations carried out by the Department of Urban Archaeology and later the Museum of London Archaeological Services.

The demography at this site is different to that of the Eastern Cemetery. The number of males and females was very similar but, due to poor preservation, only approximately one third of the adults could be assessed for sex. There were very few juveniles at the site and very few individuals over the age of 46, a fact that could represent the real demography of the population, reflecting the migration of adults into the population who died at a young age; alternatively it could be a result of burial practice that preferred a certain demographic at this location (Mikulski and Redfern 2009).

4.1.1.8 *Early Medieval*

The departure of the Roman administration from Britain in the early fifth century resulted in the collapse of some of the imposed infrastructure. Towns predominantly went into disuse, and any towns which could be argued to exist in this period would have been little more than large villages with low population density used as market centres (Hamerow 2002). As there is little contrast in this period in terms of environment within the region of this study, Southeast England, the only real contrast would be a result of status. Unfortunately, the number of high status individuals excavated from this period in this region is too low to create a meaningful sample for comparison. For this reason the human remains excavated from Cannington in Southwest England was chosen as a comparison. The geography of the country would result in a small difference in climate between these two sites. As climate is noted in the clinical literature to be a known cause of, or at least a contributor to, respiratory disease, any difference found in the prevalence of respiratory disease in these two samples could be argued to be due to this climate difference.

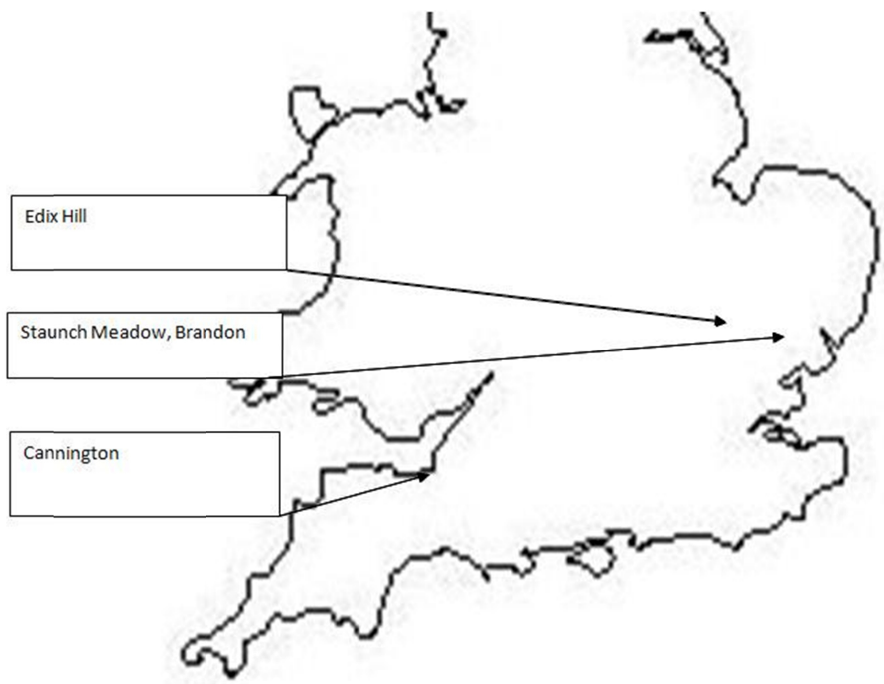


Figure 4.5: Location map of Early Medieval sites used in this study

4.1.1.8.1 Cannington

Original osteological analysis	Brothwell *et al* 2000
Location (county)	Somerset
Date of Use	3^{rd} C to 8^{th} C
Date of excavation	1962-1963
Environment	Rural
Status	N/A
Number of individuals excavated	542
Numbers of individuals examined in this study	131
Curated	Natural History Museum, London

The cemetery located in the Cannington Old Quarry, 2km from the village of Cannington in Somerset, was known from the unearthing of human remains for over a century. A great deal of the human remains were lost without any form of recording. Anecdotal evidence suggests that, perhaps 1000 remains were lost during the quarrying. Recent estimates based on density of graves uncovered during the modern excavation, however, suggest the figure may have been much higher, and there could have been as many as 5000 graves at the site (Rahtz *et al*. 2000).

The quarry went out of use in 1939 when a new quarry was created elsewhere, but in 1961 the new quarry became dangerous and the old quarry at Cannington was reopened (Rahtz *et al*. 2000). The rescue excavations took place between 1962 and 1963 before quarrying was due to resume. The cemetery was dated between AD 200 and AD 700 based on artefacts and carbon 14 dating, but was predominantly in use between the 4^{th} and 6^{th} centuries. A maximum of 542 burials were recovered, of which at least 270, approximately 70% of the remains with age estimates, were adults older than 15 (Rahtz *et al*. 2000). The distribution of grave goods and funerary rites suggests that this may have been an early Christian cemetery, but there were also graves consistent with pagan rites (Rahtz *et al*. 2000). Of the excavated material, there were high numbers of adolescents and females. Females outnumbered males 1.6:1 (Rahtz *et al*. 2000). As this is clearly only a sample of the entire cemetery, it is possible that these adolescents and females were concentrated in this area of the cemetery while males were concentrated elsewhere. It is also possible that males were buried outside of Somerset as a result of military activity or emigration (Rahtz *et al*. 2000).

Metal working was commonly seen in many of the sites in western Britain and Ireland with evidence of metal working in the form of ovens and bellows (Rahtz *et al*. 2000). Many of these sites are considered to be high status, and the metal working may have been carried out by craftsmen under the patronage of high status individuals (Rahtz *et al*. 2000). Unfortunately the incompleteness of the cemetery and the lack of material evidence make it difficult to reconstruct the lifestyle of this population and can only be inferred from other populations in the region (Rahtz *et al*. 2000).

4.1.1.8.2 Southeastern Sample

4.1.1.8.2.1 Edix Hill

Original osteological analysis	Duhig 1998
Location (county)	Essex
Date of use	6^{th} C to 7^{th} C
Date of excavation	1989 to 1991
Environment	Rural
Status	N/A
Number of individuals excavated	150
Numbers of individuals examined in this study	43
Curated	Cambridge County Archaeological Services

The cemetery at Edix Hill, located on the western edge of Barrington parish, close to the village of Orwell 12km southwest of Cambridge, was first noticed in the 1840 when a sword burial was discovered (Malim and Hines 1998). Other bones were found in subsequent years but the cemetery was only recorded in 1860 when it came under threat by drainage works. Approximately 40-50 burials were investigated at this time. A contemporaneous cemetery just north the modern village of Barrington, known as Hooper's field or Barrington B, was also found nearby (Malim and Hines 1998). The exact location of both cemeteries were later lost and there was some speculation that the two excavated cemeteries were perhaps the same cemetery found twice and described with different locations. This theory seemed even more likely since they were in use at roughly the same time. This theory is now, however, thought to be implausible (Malim and Hines 1998) and Barrington B is thought be a second population. There were no nearby settlements associated with either cemetery. The land was likely used as a cemetery by two different local settlements because it was not attractive for agriculture as a result of being overly wet in the winter (Malim and Hines 1998).

The lost cemetery of Edix Hill was rediscovered in 1987. The previous analysis noted the remains were damaged by ploughs, drainage, and agricultural chemicals. The graves were also looted when metal detecting gained popularity (Malim and Hines 1998). As this activity could not be ceased through protection of the land, the Cambridge County Council excavated approximately half of the cemetery between 1989 and 1991. The damage caused by agricultural activity, in addition to the previous 19th century excavations and metal detecting, meant that many remains were often damaged, disarticulated, or robbed of grave goods (Malim and Hines 1998). The human remains were dated between the early 6th century and early AD 7th century, a period of approximately 150 years. The cemetery of an estimated 300 individuals buried during this time likely served a community of between 50 and 65 people (Malim and Hines 1998).

Only inhumations were found in the cemetery. The remains were placed in open coffins fully clothed and often accompanied by prestige items (Malim and Hines 1998). There were a few prone burials, as opposed to flexed, some of which appear to have been moved after having already significantly decayed. Why these remains were treated differently is unclear (Malim and Hines 1998).

4.1.1.8.2.2 *Staunch Meadow, Brandon*

Original osteological analysis	Anderson 1990
Location	Suffolk
Date of use	8th C to 11th C
Date of excavation	1980 to 1987
Environment	Rural
Status	N/A
Number of individuals excavated	158
Numbers of individuals examined in this study	16
Curated	Suffolk County Council Archaeological Service

Staunch Meadow is located in the valley of the Little Ouse River, or the Brandon River, in modern day Brandon in Suffolk, approximately 40 miles west of Norwich and 40 miles north of Ipswich. The site is located at what was probably the lowest crossing of the river, and when the river flooded it probably would have turned the site into an island. Rescue excavations began in 1980 when it was decided that the area would be levelled for use as playing fields. The excavation of this area occurred between 1980 and 1982, but further excavations of the surrounding area continued until 1987 (Carr *et al*. 1988).

Features on the site included the remains of 25 buildings and a chapel. The remains of the houses included post holes, wood, and clay, which have been interpreted as making up the walls. Hearths were found in all of the buildings as well as internal walls. There was no evidence of the specific activities carried out in the buildings, but it is believed that they were used both for habitation as well as for other activities, such as crafts and agriculture. There is also evidence of craft production on the north side of the island. These activities included metalworking, pottery, woodworking, boneworking, and glassmaking (Carr *et al*. 1988).

There were burials to the south and north of the church. The burials, based on radiocarbon dating, date from the eighth to the eleventh century. Although more than 300 skeletons were uncovered, only approximately 158 skeletons were excavated, and the preservation was generally poor (Anderson 1990).

4.1.1.9 Late Medieval

The Late Medieval Period, which extends from the Norman invasion in the eleventh century to the Reformation in the sixteenth century, provides several interesting contrasts. While cities first appear at the end of the Early Medieval Period, by the end of the Late Medieval Period much of the population migrates out of rural areas into the cities and towns (Dyer 2000). The increasingly high population density of cities in this period resulted in a high density of hearths used for heating and cooking in a relatively small area, and consequently a higher concentration of smoke in the atmosphere (Brimblecombe 1987). This, combined with pollution from commercial businesses and craft production in the city centre, and for the more polluting industries on the edges of the cities, where they could be close to the markets, would have meant a higher exposure to atmospheric pollution than any population before (Brimblecombe 1987). As many individuals would have specialised in areas of trade or crafts, which no longer left them free to produce food for their own subsistence, the decreasing proportion of the population still in the country would have become responsible for providing goods not just for themselves and their lords, but for those who lived in the cities (Dyer 2000). This in turn would lead to the more intensive agriculture.

The almost universal Christian tradition of burial in cemeteries during this period means large populations are buried together in parish cemeteries (Dyer 2000). If the population the parish served represented a particular social stratum, which would depend on the cost of living in the area of the church, the population could be made up exclusively of a particular status group. Ideally, the samples from this period would be chosen as follows. Two samples would be made up exclusively of individuals who spent their lives in the city. One would be made up of individuals who without doubt were consistently very wealthy. The other would be made up of individuals who were known to be low status and ideally who lived on the edge of the city which, in addition to being a less expensive area in which to live, would have contained many of the most polluting industries which were not legally allowed to be located within the city centre. Two samples, high and low status, would also be recorded from exclusively rural populations whose main form of subsistence relied on agriculture.

Unfortunately, the available samples were less than ideal. St. Mary Graces is a relatively mixed population containing a proportion of high status individuals who were recovered from the church crypt (Bekvalac 2008). This site is only relatively high by comparison to the two cemeteries with which it is contrasted. For a low status sample, there were no skeletal populations available from the edge of medieval London, which is now under modern central London. Two populations from central London, St. Nicholas Shambles and Guildhall Yard east, were analysed. The exact lifestyle of the population who were buried at St. Nicholas Shambles is not well known. The population died relatively young (average age recorded by White 1988, middle age adult) with few skeletal indicators of disease, a fact that could suggest, given that they died so young, they must have died of acute conditions or of chronic conditions that affected the soft tissue alone. It is more likely that a less wealthy population would be more susceptible to disease as a result of poor diet and poor living conditions. They also would have likely less access to medical treatment, making early death a more likely outcome (White 1988). Unfortunately, survival of the sinuses was poor at this site and only twenty individuals were adequately preserved for this study. In order to increase the sample size, the population from Guildhall Yard East, known to be made up of individuals involved in various trades and manual labour, many of whom would have been exposed to pollution in their day to day life, was also examined (Bowsher *et al*. 2007). Unfortunately, it too was a relatively small sample. As no other sites from this region were available for study, this sample remained relatively small.

Ideally, the two other samples would be taken from the rural environment. The first, a relatively low status group, would ideally be made up of a population who were known to have spent their lives in small villages where they engaged exclusively in agriculture. The final sample would ideally be representative of a population who lived in the country but did not engage in agriculture, and as a result would not have been exposed to large concentrations of particulates such as dust and pollen to the same extent as would be the case through working in the fields.

Abingdon Vineyard was chosen for this study because the medieval cemetery alone was made up of approximately 500 individuals, which contributed a sample of over 150 individuals with maxillary sinuses and ribs preserved. The cemetery, in spite of being located in the town of Abingdon, would have been made of individuals from the surrounding countryside as well as the town (Wakely *et al*. 1998). While the sample undoubtedly includes individuals who spent their whole lives in town, the hope was that overall the population was representative of an agricultural population. As a high status contrast, Merton Priory, a monastery was chosen. These men lived in a relatively rural environment, but would not have been exposed to the dust, fungus, and pollen that would be pervasive if they were engaging in intensive agriculture. They did however engage in some light horticulture in addition to their other clerical activities. Unfortunately, choosing this population meant that the sample was almost exclusively made up of men, resulting in very little contrast by sex. While there were women buried in the cemetery, either wives of wealthy patrons or women who worked in the monastery (Miller and Saxby 2007), for obvious reasons neither of these possibilities makes them representative of the sample and differences could be expected on the basis of differences in lifestyle alone. While some of the men buried here would also have been servants or wealthy patrons, it is hoped that with such a large sample, these individuals will not affect the prevalence rate significantly.

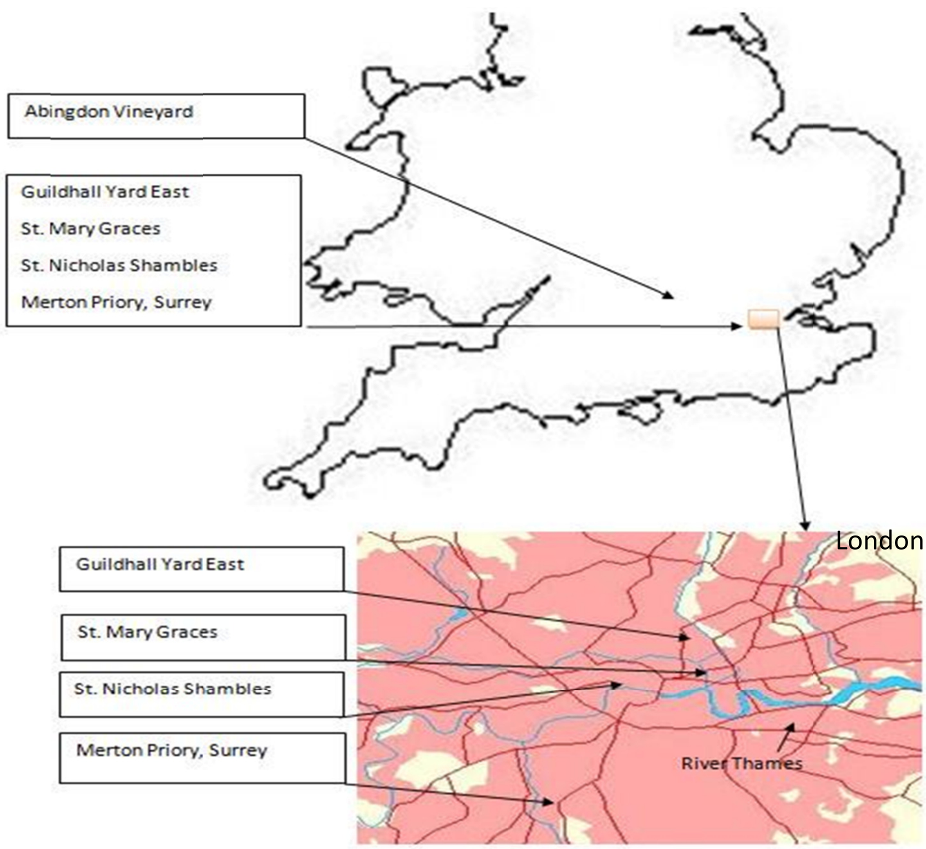


Figure 4.6: Location map of the Late Medieval Sites used in this study

4.1.1.9.1 Abingdon Vineyard, Medieval Cemetery

Original osteological report	Not referred to
Location (county)	Oxfordshire
Date of use	AD 1100 to 1540
Date of excavation	1889 to 1990
Environment	Rural
Status	Low
Number of individuals excavated	Approx. 485
Numbers of individuals examined in this study	142
Curated	Natural History Museum, London

The medieval cemetery of Abingdon Vineyard, dated between AD 1100 and AD 1540 and located on the outer area of the Abingdon Abbey grounds, was discovered in the current town centre of Abingdon. The area referred to as 'The Vineyard' was excavated by Oxford Archaeology between 1989 and 1990 in the course of constructing new buildings for Abingdon Borough Council (Allen 1990). The cemetery served the lay population of the town and the surrounding countryside, but not the monastic community from Abingdon Abbey (Allen 1990). In addition to the medieval human remains, a civil war cemetery was excavated from an orchard in the north west of the same site. Below the medieval cemetery was evidence of continuous settlement from the Iron Age to the Early medieval in the form a sequences of settlements and some Roman burials (Allen 1990). The earliest burials in the eastern part of the cemetery appear to begin in the 12th century based on cist burials and stone 'earmuffs'. Further burials were placed over the remains of a wooden bell tower which was destroyed in the early 14th century (Allen 1990). A later extension appears to have been added to the west part of the cemetery and may be as late as the 16th century, based on a ditch that forms the western boundary of the cemetery.

Located at the meeting point of two rivers, the remains of at least 10 species of fresh water fish have been recovered from the town of Abingdon, suggesting fishing may have played a role in industry.

4.1.1.9.2 Merton Priory

Original osteological report	Conheeny 2007
Location (county)	Surrey
Date of use	1117 to 1538
Date of excavation	1977 to 1983
Environment	Rural
Status	High
Number of individuals excavated	738
Numbers of individuals examined in this study	103
Curated	Museum of London Centre for Bioarchaeology

The Augustinian Priory of St. Mary Merton, located in Surrey, 11.3km south of London, was excavated by the Museum of London Department of Greater London Archaeology (DGLA) between 1977 and 1983 as a rescue excavation prior to redevelopment, and again between 1986 and 1988 by the Museum of London Archaeology Services (Miller and Saxby 2007). The 738 burials recovered dated between AD 1117 and AD 1538, the period of monastic occupation on the site. The priory was founded in the 12th century as a small monastic house and continued to expand through its occupation, particularly in the 13th century following the collapse of the tower. This sudden growth may have been due to increased funds from benefactors (Miller and Saxby 2007).

The individuals buried at this site were part of the monastic community as well as some wealthy members of the lay community. The location of the burials in particular cemeteries or in buildings was dictated by whether the individuals were monastic or laypeople as well as by rank in the monastery. The north cemetery contained a mixture of lay and clerical internments while the area to the Southeast of the church was reserved principally for canons. The chapter house appears to have been reserved for priors and some high status laity (Miller and Saxby 2007). The number of burials increased in the 14th century, not likely as a result of a higher mortality rate, but because the canons allowed more high status lay people to be buried there in order to increase revenue (Miller and Saxby 2007).

Seventy-seven percent of the adult cemetery population was male (Miller and Saxby 2007). Most of the individuals buried in the cemetery were between 26 and 45 years old, with the next highest group being individuals over 45. The smallest group, making up only 5% of the samples were between 17 and 25 years old, suggesting that the average lifespan of the population was relatively high. The dearth of women and children confirm this was a monastic cemetery. The few women and children found were most likely servants employed by the priory (Miller and Saxby 2007). The bioarchaeological evidence as well as evidence of medical intervention suggests the population did not suffer from chronic illness or stress, and had access to good diet and medical care (Miller and Saxby 2007).

Everyday life in the monastery depended on rank. The highest rank was attributed to the priors. There are 34 known priors, 20 of whom died in office. They were typically buried in the chapter house. However, there were more individuals buried in the chapter house than there were priors, suggesting some individuals buried here were not priors; they may have been other senior monastic personnel or high status laity. Ranked below the priors were the canons. Their daily life was structured by several services of communal worship, both day and night. The remainder of their time was spent reading, preaching, worshiping, writing, correcting books, making or repairing clothing, making items such as wooden spoons, candlesticks, woven mats, or working in the gardens and fields (Miller and Saxby 2007). Ranked below the canons were the novices who were seeking admission to the monastery either as adults or, before a change in law in the 13th century, as children placed in the priory as oblates. Following the change in law in the 13th century postulants were only admitted after the age of 17, usually between 17 and 19 (Miller and Saxby 2007).

Also living in the monastery were servants and lay people. In the Augustinian order there were typically few lay brethren. There is no evidence of any lay brethren at Merton Priory although it is probable that there were some (Miller and Saxby 2007). The servants would have been responsible for carrying out menial tasks within the monastery (Miller and Saxby 2007). In addition to the servants there were other permanent inhabitants known as corrodians. These individuals were usually clergyman or prosperous citizens of London who made private arrangements with the priory to build homes within the priory as well as receive stipulated rations of food, drink and other commodities such as clothing and candles (Miller and Saxby 2007). There were also more transient inhabitants including guests or travelers of any social status, including the sick (Miller and Saxby 2007).

Most of the religious artefacts from the site were removed from the priory after the dissolution, but artefacts of nonreligious daily life including kitchen equipment remain to be excavated. While the canons and lay brethren took a vow of poverty, other inhabitants of the monastery did not. The remains of clothing, accessories, and other personal items belonging to these other individuals were recovered. Monastic meals consisted of bread, cheese, vegetables, beans, and cereals. On special occasions extra dishes of fish and eggs were served. Canons were only allowed meat when ill or during bloodletting, but meat may have been consumed with guests (Miller and Saxby 2007).

The area surrounding Merton Priory was ideal for agriculture. There was a constant supply of fresh water, as well as a hay meadow, access to fresh fish, and land for growing fruit, vegetables and cereals. By the time of the dissolution the priory contained gardens, orchards, stables, dovecotes, mills, ponds, vineyards, and fisheries (Miller and Saxby 2007). Light horticulture, as mentioned above would have been a daily activity for the canons, which could have exposed this segment of the cemetery population to increased levels of allergens compared to the others living in the priory (Miller and Saxby 2007). However, as much of their time was spent indoors on less physical tasks it is expected that their exposure would be significantly lower than a low status population who subsisted solely on agriculture. Alternatively, the canons and other religious segments of the priory would have, as a result of spending a great deal of time indoors and likely working by candle light or in an environment which included the consistent burning of incense, been exposed to higher levels of domestic pollution such as smoke and dust.

4.1.1.9.3 St. Mary Graces, London

Original osteolgical analysis	Bekvalac and Kausmally In prep
Location (county)	London
Date of Use	1350-1540
Date of excavation	1986-1988
Environment	Urban
Status	High
Number of individuals excavated	420
Numbers of individuals examined in this study	78
Curated	Museum of London Centre for Bioarchaeology

St. Mary Graces, formerly known as Royal Mint, was excavated between 1986 and 1988. The excavation uncovered a large burial ground associated with the Cistercian abbey of St Mary Graces composed of approximately 420 burials dated between AD 1350 and AD 1540. These burials were divided between the churchyard and those interned in the abbey. The inhumations in the churchyard, which went out of use in 1405, were lay burials overlying the earlier western catastrophic cemetery. They were standard medieval Christian burials with no apparent differentiation in social status (Bekvalac 2008). The abbey church dated from AD 1353-1538 and had intramural burials mainly concentrated in the nave, with some found in the choir, chancel, chapels, porch and cloister. The burials were high status and wealthy individuals buried in a standard medieval Christian style (Bekvalac 2008).

4.1.1.9.3.1 Guildhall Yard East

Original osteological report	Cowal 2007 Wellcome Osteological Research Database
Location (county)	London
Date of use	11th C to 13th C
Date of excavation	1992-1997
Environment	Urban
Status	Low
Number of individuals excavated	68
Numbers of individuals examined in this study	20
Curated	Museum of London Centre for Bioarchaeology

The sample referred to as Guildhall Yard East, was a lay cemetery excavated from the churchyard of St. Lawrence Jewry, dating between the late 11th century to the early 13th century. The site, located on Basinghall St. in east London, was excavated between 1992 and 1997 by the Museum of London Archaeological Services. The church was known as St. Lawrence at the time, the word Jewry being added later to reflect the increasing Jewish population in the area in the 13th century (Bowsher *et al* 2007). The church most likely began as a private chapel for a nearby estate, but in the 11th century the church was rebuilt in stone to make it a parish church and near the end of the 11th century timber houses were erected on the streets nearby (Bowsher *et al* 2007). The remaining rubbish pits and latrines demonstrate that this area was intensively used, and the waste suggest that livestock were kept in stables and there was extensive production of crafts, such as wood-working and shoemaking (Bowsher *et al.* 2007). The remains of 35 timber buildings were excavated from the Guildhall area. Some of these would have been used for the storage of livestock, but others have evidence of domestic activity. For the most part the walls were made of wattle, and maybe daub. The roofs were possibly made of thatch.

Most of the timber buildings have evidence of domestic occupation and had at least one hearth, and in some cases one at either end of the building. These appeared to have been used for domestic use, such as heating and cooking. There was no evidence for buildings whose main purpose was craft production; rather, based on the domestic waste, all of the buildings were likely lived in as well as used for craft production. The hearth in one building had evidence of slag, which suggests it was used for metalworking (Bowsher *et al.* 2007). This evidence helps support the strong association of this area with metalworking from the eleventh century to the sixteenth century (Bowsher *et al*. 2007). Within at least four buildings there were hearths that were enclosed for use as ovens. These may have been used for baking or drying grains (Bowsher *et al.* 2007). There were some hearths found outside the timber houses and in some cases several hearths together, which have been interpreted as cookshops. Based on the waste found in association with these areas, they appear to have been used for commercial cooking, perhaps to sell food to passers-by and people who worked nearby (Bowsher *et al*. 2007). Smoke holes in the roofs of these houses would have helped increase ventilation. They would have also allowed in some light, in order to limit the need to use fire for light. However candles, oil burning lamps, and fire would have been the main source of light in the houses whose only other source was through the door, and possibly some very small unglazed windows (Bowsher *et al*. 2007). More positively, the evidence for crafts, such as metal-working, leather-working, horn working, tanning, woodworking, baking, and textile production, as well as the universal use of open hearths helps in interpreting the impact of domestic pollution and occupation on respiratory health (Bowsher *et al* 2007).

Unfortunately, this population was not an ideal example of a low status urban population. Its early date compared with the other Late Medieval populations examined here makes it less comparable. It also means the population density was not as high as might be expected from a population who lived in the "slums" outside the city centre. Unfortunately, there were no available human remains from such populations. There is also some evidence of higher status foods, such as peaches, found in the remains from this site. While these high status remains are not common, it does call into question the relative status of the group.

The burials were in some cases in wood coffins, or at least had wood covers. This wood would have been relatively expensive, but cheaper than higher status stone coffins. The burials were very similar to those at St. Nicholas Shambles described below. Based on the remains and historical documentation, the area around Guildhall appears to have been a mix of status groups, particularly from the end of the twelfth century and thirteenth centuries as the population grew denser (Miller and Saxby 2007).

Seventy-two burials were recovered. Preservation of the human remains was generally good with 70% being more than half complete and 60% being more than 75% complete (White 2001). Based on the demographic information reported by White (2001), there were roughly equal numbers of males and females as well as a high proportion of adolescents in the cemetery. Like St. Nicholas Shambles, discussed below, the estimated ages at death were all below 45 years, with only two exceptions. While there was evidence of joint disease, this was not unusually high and there was no evidence of malnutrition in the form of scurvy or rickets. The prevalence of dental disease was also low, again similar to the results found for St. Nicholas Shambles (White 2001).

4.1.1.9.3.2 St. Nicholas Shambles

Original osteological report	White 1988
Location (county)	London
Date of Use	1187 to 1551
Date of excavation	1975-1979
Environment	Urban
Status	Low
Number of individuals excavated	234
Numbers of individuals examined in this study	21
Curated	Museum of London Centre for Bioarchaeology

The cemetery of St. Nicholas Shambles was found during an excavation of Newgate Street prior to the construction of the British Telecom Centre. The excavations were carried out between 1975 and 1979 by the Department of Urban Archaeology from the Museum of London. The excavated area contained the remains of the small parish church, with most of its cemetery on the north side of the church and some separate burials on the east side. Documentary evidence relating to the church dates to AD 1187, with a possible reference appearing in AD 1144. By the sixteenth century, the church occupied an area on approximately 30m^2. According to documentary evidence the church went out of use between AD 1548 and AD 1551 (White 1988).

Like at Guildhall, the north-west area of the city, which included the area where St. Nicholas Shambles was located, was well known for its association with metal-working, but if any of the individuals who are buried here were involved in this trade it is impossible to say.

The graves themselves were not datable by stratigraphy or grave goods. Ceramics found in the cemetery dated to between the eleventh and twelfth centuries. Two hundred and thirty-four graves were excavated, although only 36 could be considered complete. There were few children or individuals over 45 years old reported. It is possible that some older individuals were not accounted for as there were many individuals who could not be aged. It is also possible that the individuals buried here were a subset of the population with children being buried elsewhere (White 1988). Although there is little evidence of pathology in the population, the seemingly low age of death and high levels of dental hypoplasia could suggest that the health of the population was relatively poor. It is likely that they did not suffer from chronic conditions or, if they did, they only suffered from chronic conditions that did not affect the skeleton (White 1988).

4.1.1.10 Post Medieval

This period, which extends from the reformation in the sixteenth century to the end of the nineteenth century, is perhaps the most interesting from the point of view of this study. It is during this period that Britain had its Industrial Revolution. Massive quantities of atmospheric pollution were created, noticeable for their colour-changing and corrosive effects on the surrounding environment, and noted in documentary sources for its effects on human health (Brimblecombe 1987).

While the ideal comparison would be one high and one low status urban group in contrast to a rural population, in this period the vast majority of the population, certainly for that which represents human remains excavated in the Southeast, lived in cities. As a result, three samples were chosen that meet these ideals as closely possible. The two populations from St. Brides' parish were buried according to social status at death (high and low), and so, can be examined as a contrast of social status. But, their access to wealth for burial at the time they died, or the wealth available to those who paid for their burial, may not be representative of their status in life. In addition to the possibility that someone wealthier than they paid for their burial, money could be acquired and/or lost within the course of a lifetime. For example, located nearby St. Bride's Church in this period were a workhouse and a debtors' prison, which likely contributed to the population of the lower crypt. One of the individuals buried in the lower crypt was found to have a gold filling in his tooth, suggesting that at some point he had access to expensive dental care. It is possible that he lost his wealth in his lifetime and ended up in the debtor's prison, later to be buried in the lower crypt. Unfortunately, how long before his death he fell into debt, assuming this is the case, is unknown. Conversely, of the recorded individuals in the high status crypt, some of the individuals were known to have risen to positions of power from relatively humble backgrounds, while others, in spite of being buried in a high status crypt, spent their life in poor environments before being buried in the crypt by wealthy relatives. In spite of these anomalies, the fact that these two populations come from the same parish and likely lived within a small geographic area makes these populations an ideal contrast of social status, having removed the potential causative factor of environment (Scheuer and Black 1995).

These two urban populations were contrasted with the population from Chelsea Old Church. Chelsea during these individuals' lifetimes would have been outside of central London and relatively rural. While the cost of living in the area would suggest the population was generally high status, the availability of nameplates associated with some burials, and associated records, show that at least some of the people were involved in trade, some of which might have exposed them to poor air quality for large periods of the day (Cowie *et al*. 2008). Similarly, the position of the population on the River Thames, so close to central London, would have made traveling into the city easy (Cowie *et al*. 2008). This would have been an advantage to living in this area and it is likely that individuals from this population spent significant periods of time in the more polluted urban centre within their lifetime.

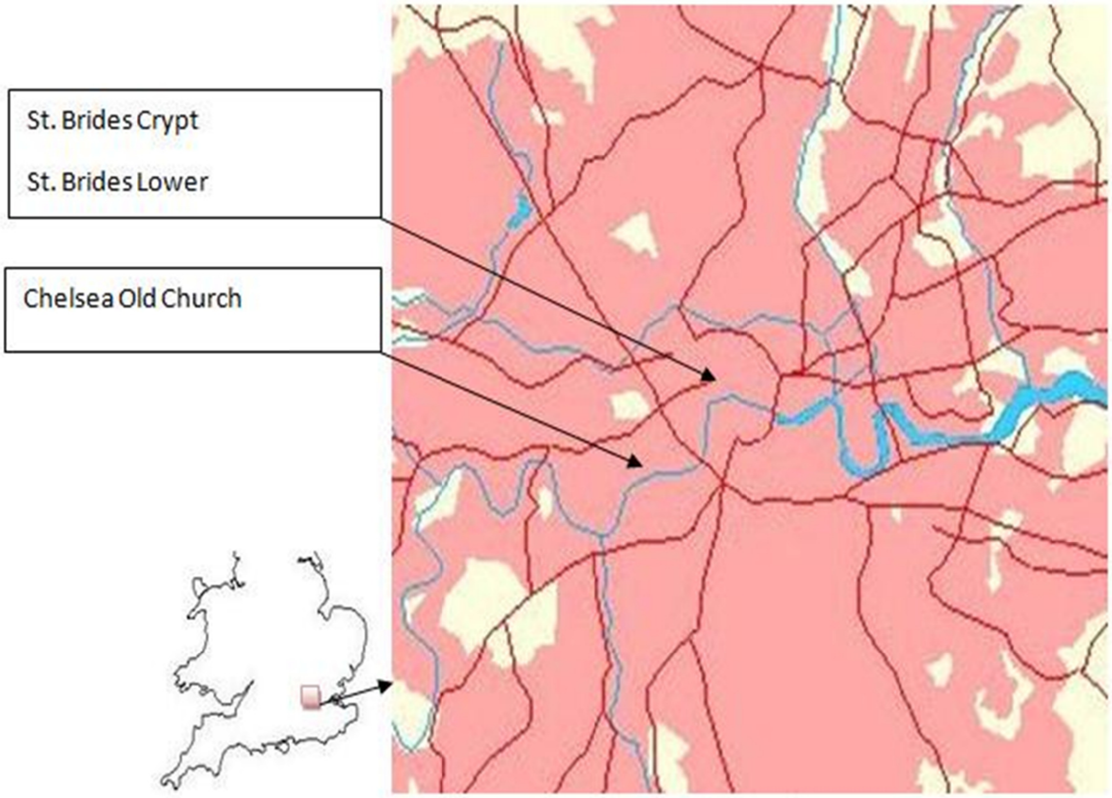


Figure 4.7: Location map of the Post Medieval Sites used in this study

4.1.1.10.1 Chelsea Old Church

Original osteological analysis	Bekvalac and Kausmally 2008
Location	London
Date of use	18th C to 19th C
Date of excavation	2000
Environment	Semi- Urban
Status	Mixed high and low
Number of individuals excavated	290
Numbers of individuals examined in this study	77
Curate	Museum of London Centre for Bioarchaeology

Excavations were undertaken by the Museum of London archaeological services in 2000 at a site north of All Saints, Chelsea Old Church following the demolition of the vicarage and Peyt House, and prior to building on the site. The burials were discovered in an evaluation trench, having thought to have been removed 40 years earlier, before the building of the church hall. The remains were dated to between the eighteenth and nineteenth centuries based on documentation and carbon 14 dates. Twenty-five (8.6%) of the coffins had coffin plates, which dated between AD 1712 and AD 1842 (Cowie *et al*. 2008).

In the 16th century, Chelsea was a small village that became popular with high status individuals because it was far enough away from the city to make it safer during the plagues (Cowie *et al*. 2008). It was also far from major roads, but its location on the Thames meant it was picturesque and within easy reach of the city centre by boat (Cowie *et al*. 2008). In addition to the high status population living in this region, there are also the remains of buildings belonging to lower status households, including farmers, artisans, and watermen (Cowie *et al*. 2008). In the 17th century, Chelsea began to grow, particularly following the construction of the Royal Hospital. By the 18th century, the formerly large village had become a London Suburb of approximately 300 houses. In spite of its London location, Chelsea remained somewhat rural (Cowie *et al*. 2008).   Most of the population until the 19th century still worked in agriculture and Chelsea was surrounded by fields, orchards, nurseries, and market gardens. From the 18th century Chelsea also became a popular resort for Londoners, and historical documentation suggests the population was relatively healthy and prosperous (Cowie *et al*. 2008).

Approximately 290 individuals were excavated from the parish cemetery. The preservation was generally good, although some were damaged by later graves or building work on the site. The cemetery population was drawn from the whole parish including the wealthy gentry and poor individuals. Documentation of occupations carried out by individuals in the cemetery population included both professionals and tradesmen. Some examples include bricklayers, carpenters, a builder, an apothecary, a butcher, a brewer, a vintner, a pastry cook, a printer, lawyers, and army officers (Cowie *et al*. 2008).

4.1.1.10.2 St. Bride's Crypt

Original osteological analysis	Scheuer and Black 1995, unpublished
Location (county)	London
Date of use	Early 19th C
Date of excavation	1940-1950
Environment	Urban
Status	High
Number of individuals excavated	244
Numbers of individuals examined in this study	134
Curated	St. Bride's Church Fleet Street

The crypt at St. Bride's Church, Fleet Street was sealed in 1854. It was rediscovered in 1940 after damage to the church by a bomb during the Second World War uncovered a charnel house, and the post medieval crypt, which housed the high status individuals from the early 19th century. The individuals had been interred in coffins with coffin plates but, as a result of the bomb damage, the remains had to be quickly reboxed and moved (Scheuer and Bowman 1995). The historical documentation associated with this population, even more so than at Chelsea Old Church, makes this site unique in this study, and also invaluable. In this instance, age and sex can be assigned with certainty, and, for 163 individuals, cause of death as well. There were a number of individuals interred at this site who had various types of respiratory disease recorded as their cause of death. Several individuals were recorded as having "consumption", while one individual was recorded as having "water on the chest" and another "pleurisy". Given the close proximity of the pleura to the visceral surface of the ribs, it possible that chronic inflammation of this tissue could cause rib periostitis. Other causes of death were less specific, but still could still suggest respiratory disease, including "disease of the chest" or "chest complaint." According to Scheuer and Bowman (1995) 52% of deaths were attributed to some form of respiratory disease. However the vast majority of these were tuberculosis. All but approximately five percent of the individuals whose causes of death are believed to be tuberculosis had adequate skeletal changes for this diagnosis, which is expected given how late pathognomonic bone lesions appear in the disease (Roberts and Buikstra 2003).

It can be assumed, on the basis that burial in the church in lead coffins was an expensive form of funerary treatment, that the individuals buried here were wealthy, or certainly buried by wealthy individuals. In addition to inferences about lifestyle, there are historical records relating to some of the named individuals from this population, which can provide more detailed information, including where they lived and any occupation, although occupations were only listed for 27% of males, and no occupations were indicated for females (Scheuer and Bowman 1995). However, given the high status of the individuals buried here, it is unlikely that any individual would have worked in an occupation that exposed them to unusually high levels of air pollution. Even though there is one individual who is listed as a coal merchant, his treatment after death and the historical records suggest he owned the business rather than worked directly with the materials (Scheuer and Bowman 1995).

4.1.1.10.3 St. Bride's Lower Crypt

Original osteological analysis	Kausmally 2008 Wellcome Osteological Research Database
Location (county)	London
Date of use	17^{th} C to 19^{th} C
Date of excavation	1990
Environment	Urban
Status	Low
Number of individuals excavated	544
Numbers of individuals examined in this study	122
Curated	Museum of London Centre for Bioarchaeology

When the churchyard associated with St. Bride's Church, located on Fleet Street, became too overcrowded, a second churchyard on nearby Farringdon Street was created. The churchyard was in use from the seventeenth to the nineteenth century and was subsequently used to bury the less wealthy segment of the population who lived in the parish. It was also likely used to bury individuals who died in the nearby Bridewell workhouse and Fleet Prison, which also housed individuals who were in debt (Kausmally 2008).

The churchyard was excavated in 1990 by the Museum of London Archaeological Services and over 600 graves were uncovered. Subsequently 544 human skeletons were excavated and analysed. The preservation was generally very good. The high risk of mortality for children confirms the poor living conditions. While parish records record dates of birth, death, and causes of death, there were so few coffin plates that the records cannot be assigned to any specific remains (Kausmally 2008).

4.1.2 Summary

The twelve samples discussed above were chosen on the basis that they could best test the hypothesis that air quality played a significant role in the development of respiratory disease in past populations who were frequently exposed to pollutants known to cause respiratory disease in living populations. This hypothesis will be tested using the methods laid out in the next section.

4.2 Methods

4.2.1 Introduction

The focus of this study has been on the recording of two types of lesions, lesions on the inner surface of the maxillary sinuses and lesions on the visceral surface of the rib. However, in order to gain a fuller understanding of how the conditions that caused these lesions affected the population, all samples were also examined for age, sex, dental disease that could have caused chronic maxillary sinusitis, and any evidence of a specific respiratory disease, such as tuberculosis, which could have been responsible for the presence of rib periostitis. The level of preservation of the relevant elements was also recorded. These will be discussed in more detail below.

4.2.1.1 Age at death estimation

Only adults were examined in this study because the eruption of the maxillary dentition may cause pitting in juvenile maxillae, which can be mistaken for sinusitis (Lewis 1995). As a result, “adults” were defined as having a complete set of erupted dentition, including the third molars, which typically erupt between the ages of 18 and 20, depending on heredity and environment (Scheuer and Black 2004).

Age was estimated exclusively using macroscopic methods. Adult age estimation methods typically focus on degenerative changes in the skeleton, but the extent and timing of changes can differ considerably depending genetics and environment (Lovejoy *et al.* 1985a; Meindl *et al.* 1990; Wittwer-Backofen *et al.* 2008). Skeletal indicators of age can differ from population to population, from person to person, and even from skeletal element to skeletal element (Lovejoy *et al* 1985a; Meindl *et al* 1990; Wittwer-Backofen *et al* 2008). As a result, previous tests of these methods have determined that no single method is completely accurate. When combined, however, the accuracy increases. To minimise error, all of the following methods were used wherever possible, and broad age categories were used rather than specific age designations.

These categories, adapted from Buikstra and Ubelaker (1994) are as follows

- Young Adult: 18-34 years old
- Middle Adult: 35-49 years old
- Old Adult: 50 years old or more

Additionally, where insufficient evidence of age was available, the individual was recorded as “adult”, as all individuals in this study had to have completely erupted maxillary dentition in order to be included.

4.2.1.2 Dental attrition

Molar attrition was recorded using the standards defined by Brothwell (1981), which was developed on British skeletal material dating from the Neolithic to the Medieval Period, and Miles (2001), which was developed on Anglo-Saxon skeletal remains. The rate of tooth wear is highly dependent on diet, environment, and the use of teeth for other activities (Miles 2001). It is also limited in ageing the older individuals as the highest age category described in this method is 45+. This is less problematic as the highest age category in this study is adults over 50 years old. However, other methods are necessary to determine if the person falls at the top end of the middle adult category or within the old adult category. As the preservation of the maxilla was a requirement for inclusion in this study, there were a disproportionate number of individuals with preserved dentition to examine for age estimation. However, in some populations where the young individuals, as defined by dental development or other reliable ageing methods, such as epiphyseal fusion, had atypical occlusal wear, the estimates for the remaining population were adjusted accordingly (Miles 2001). Dental attrition, however, was preferably used in conjunction with other methods.

4.2.1.3 Fourth sternal rib end

As with the dentition above, the preservation of ribs was, in most cases, a requirement for inclusion in this study, and as a result an age estimation method based on the ribs was frequently used. The method was first developed by Iscan *et al* (1984; 1987) on a sample of white males. The method was then tested on and adjusted to include white females, black males and black females (Iscan *et al.* 1985; Iscan *et al.* 1987). The method of ageing is premised on the sternal end of the fourth rib degenerating from a smooth billowed surface in young adults to a more concave irregular surface in older individuals at a relatively consistent rate (Russell *et al.* 1993). However, the ribs are relatively fragile and commonly damaged post mortem (Waldron 1987). In some cases, the ribs were too badly damaged to identify the sternal end of the fourth rib, particularly in the oldest samples. Recent studies have found that in these circumstances, other sternal ribs ends can be used (Dudar *et al.* 1993; Loth and Iscan 1989; Loth 1995). While many methods are known to consistently over or underestimate the ages at death of individuals, it is believed that this method is more precise (Meindl and Russell 1998).

4.2.1.4 Pubic Symphysis: Suchey-Brooks

Todd (1921) first suggested a formal methodology for assessing the age at death from the os coxae. This method involved assessing the degenerative changes and assigning the stage of degeneration to one of 10 phases. This was further developed throughout the 1920's to include individuals from both sexes and other ancestries. This method remained in use until Brooks (1955) found that Todd's method underestimated the age at death, particularly in older individuals. In 1957 McKern and Stewart (1957) suggested an alternative method looking at three features on the pubic symphysis, the dorsal plateau, ventral rampart, symphyseal rim. This method also proved inaccurate when used to analyse populations with known ages at death. Estimating age at death based on the degeneration of the pubic symphysis was developed most recently by Brooks and Suchey (1990). Unlike with the previous methods, which were initially developed using populations of males, Brooks and Suchey examined a sample of 739 males and 273 females from a modern population with known ages at death as well as known medical histories (Brooks and Suchey 1990). This method required analysing the morphology of the pubic symphysis. The features of the pubic symphysis would place it in one of six sex-specific stages for which a range of ages are known. This range will provide the average for the group as well as the standard deviation and 95% range. This allowed researchers to narrow these ranges with relative confidence. This method is limited as unfortunately, the pubic symphysis does not often preserve in archaeological samples and in many instances where the symphysis had preserved, the cortex of the articular surface had been too damaged to accurately determine in which stage the person should be placed. The method is also limited in ageing individuals over the age of 40 years as the developmental changes to the pubic symphysis are completed around the age of 35 (Lovejoy *et al.* 1985a; Meindl *et al.* 1985; Meindl and Russell 1998). The degenerative changes that are used to define the older age categories have also been found to be inaccurate (Meindl and Russell 1998; Saunders *et al.* 1992)

4.2.1.5 Auricular surface

Unlike is the case with the pubic symphysis, degeneration of the auricular surface is thought to continue into later age groups. This area of the pelvis is also known to preserve well in archaeological contexts (Waldron 1987). For these reasons this is a useful method. However, this skeletal age indicator has not received the same amount of scrutiny as the methods examining the os coxae mentioned in section 4.2.1.4.

Lovejoy *et al (1985b)* developed the method using the Libben population and the Todd population, both from the United States. The method determined there were seven features of the auricular surface that could indicate age. These features are grain and density, macroporosity, billowing, striations, existence and appearance of an apex, activity in the retroauricular area, and stage of decreasing transverse organisation (Lovejoy *et al.* 1985b). Depending on the appearance of these features, the surface would be assigned to one of eight stages, which were roughly five year intervals. However, since this paper, researchers have analysed other known age and sex populations. The results of these previous studies have found that the method tended to underestimate the age at death of older individuals while overestimating the age of younger individuals (Bedford *et al*. 1993; Buckberry and Chamberlain 2002; Murray and Murray; Saunders *et al*. 1992). In addition to this, it was determined that the degenerative changes noted in Lovejoy *et al* (1985b) developed independently and did not necessarily occur at the same rates. This made assigning an individual to one age group difficult (Buckberry and Chamberlain 2002).

4.2.1.6 Skull sutures

The fusion and obliteration of the sutures of the skull is strongly influenced by heredity, rather than age related degeneration like the above methods (Meindl and Lovejoy 1985). As a result it may not always be an accurate indicator of age. In some individuals, sutures may fuse early, while in others they may never fuse, regardless of age. Their fusion may also be affected by pathological processes (Meindl and Lovejoy 1985). However, as there are a limited number of methods of age estimation available to examine for any given individual, this skeletal age indicator, following the method described by Meindl and Lovejoy (1985), was used in conjunction with any other available ageing methods detailed in this chapter.

4.2.1.7 Epiphyseal fusion

In juveniles and young adults whose bones are not fully fused, the epiphysis is not attached to the diaphysis, but connected by the metaphysis. As the bones grow the metaphysic is replaced by bone and the epiphysis fuses to the diaphysis. This fusion occurs at relatively regular ages, and as a result can be used to estimate age at death in individuals who are not yet skeletally mature (Scheuer and Black 2004).

As all of the individuals included in this study were adults, as defined by a complete set of dentition, this method was used to place individuals in the lower ranges of the young adult category, if they had a complete set of dentition including the third molars, and unfused late fusing epiphyses, such as the medial clavicle and baso-sphenoid (Scheuer and Black 2004).

4.2.1.8 Problems with age at death estimation

As mentioned above, estimations of age at death are imprecise and tend to underestimate the age of older individuals (Bedford *et al.* 1993; Brickley *et al.* 2004; Lovejoy *et al.* 1985a; Wittwer-Backofen *et al.* 2008). The use of wide categories in this study was an attempt to limit the inaccuracy of the ageing methods. In the instances where age was known as a result of coffin plates, at St. Bride's Crypt and some of the individuals from Chelsea Old Church, age was most likely accurate, unless the remains did not 'belong' to the associated coffin plate, as a result of movement and reboxing over the years or the date of birth was recorded incorrectly. The same bioarchaeological methods were used in these cases to check that these individuals did fall into the same age category that was recorded on their coffin plate. There were no instances where the age recorded on the coffin plate did not match the age estimated by these methods; as a result the recorded age at death was used.

4.2.2 Sex estimation

With the exception of the population from St. Bride's Crypt, who have historically documented age and sex recovered from their coffin plates, sex was defined in this study by one of five categories

- Male
- Probable Male
- Female
- Probable Female
- Indeterminate: There are no sufficient skeletal elements to determine sex, or the features are ambiguous and cannot be confidently assigned to either sex.

In the Results chapter, the categories male and probable male, and female and probable female were combined into the category male and female respectively.

4.2.2.1 Pelvic morphology

Sexual dimorphism of the pelvis is the most accurate macroscopic indicator of sex in skeletal remains. Sex was estimated using several indicators:

- **The Phenice method**: This method examines sexual dimorphic features of the ventral arc, the sub-pubic concavity, and the medial aspect of the ischio-pubic ramus. It is considered to be the most accurate method for sex estimation and was used wherever possible. However, as mentioned above, the pubic symphysis, particularly because of its position at the front of the body, does not always preserve as well as more robust bones, and is not always available to analyse (Phenice 1969).
- **The overall shape of the pelvis**: As a result of child bearing, there are necessary differences in the overall shape of the male and female pelvis. Visual examination of the sacrum, angle of the illium, and the shape of the pelvis as a whole was recorded to determine sex (Bass 1995).

- **Width of the sciatic notch**: was not preferentially used as it is not always an accurate indicator of sex, but was considered where other methods that examined the pelvis were not available and in conjunction with any other sex estimation methods mentioned below (Bass 1995).

4.2.2.2 Skull morphology

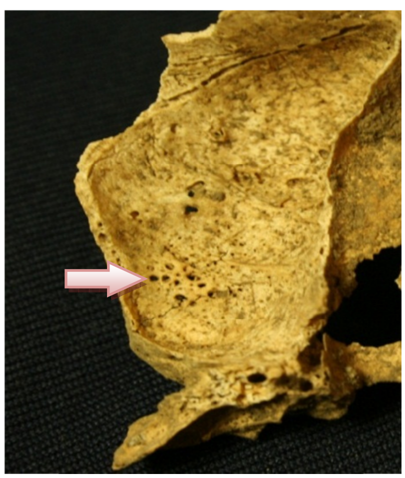
Sexual dimorphism of the skull is less accurate than dimorphism of the pelvis and depends heavily on genetics and ancestry. However, there are features of the skull that are considered reliable indicators of sex when considered together (Walrath *et al*. 2004; Weiss 2009).

- Supra-orbital torus size
- Supra-orbital margin sharpness
- Shape of the mandible
- Shape of the orbit
- Shape of the cranial vault
- Size and shape of the mastoid process

4.2.3 Chronic maxillary sinusitis

Chronic maxillary sinusitis has previously been examined in a number of studies both in the UK and elsewhere. As the methods and categories used by Boocock *et al* (1995), Lewis *et al* (1995) and Roberts (2007) were developed using a British population and have been used in subsequent British studies, these methods and categories were used in order to determine their usefulness in future studies .

Individuals were included if they had at least one sinus, where at least one quarter of the sinus was preserved, or in the case of undamaged maxillae if there was an opening of at least 5mm into which an endoscope (Rimmers Brothers Endoscope, model number CLS150-2, with Karl Storz 45 and 90 degree attachments) could be inserted. There were only a few individuals whose sinuses were so complete that an endoscope could not be inserted without drilling. In these cases the individuals were not included as permission for drilling could not be granted. These individuals were analysed for the presence or absence of lesions, osteoblastic and/or osteoclastic.

Image	**Description** *(as described in Boocock et al 1995, 486)*
	**Spicule-Type** “bone formation or thin spicules of bone that appear to have been applied to the original bone surface.”
	**Remodelled Spicules** “In some antra the spicule formations appeared to be remodelling into the walls of the sinus. Initially, spicules may merge and become plaque-like, or merge together to form bone of molten wax-like appearance.”
	**Pitted** “Fine pits were often seen in association with other types of bone change” In this study pitting (osteoclastic activity) was also found not in association with bone formation.

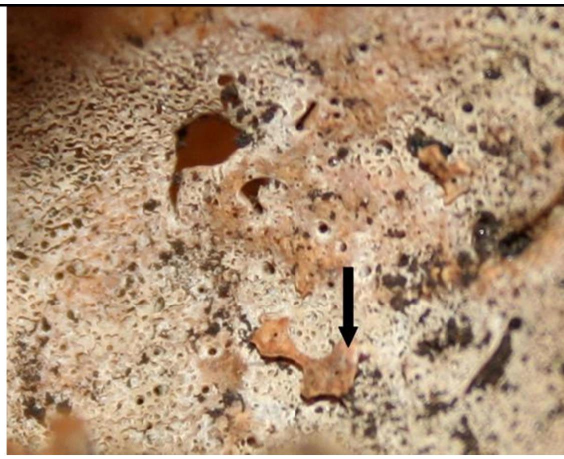
	**White Pitting** "Discrete areas of bone change were seen in a number of sinuses. These areas were often white in colour when compared with the surrounding bone and were highly pitted. In some cases there appeared to be transmission to the outer surface of the sinus" Spicule formation in image to the left is indicated with a black arrow

Table 4.1 The types of lesions referred to by Boocock et al (1995, 468) also recorded in this study

These lesions were then assigned to one of four categories: spicule type, remodelled spicules, pitting, and white pitting, as characterised by Boocock and colleagues

(1995) (see Table 4.1). The state of preservation of the sinus was recorded in order to determine the accuaracy of a "sinusitis absent" assignation. The sinuses were assigned to three categories of preservation, less than 25%, between 25% and 75%, and greater than 75% based on the approximate percentage of the whole sinus preserved (Buikstra and Ubelaker 1994). In cases where less than 25% of the sinus was available, a description of the location and amount of preserved bone was written or a diagram sketched. The sinuses with sinusitis present were examined for alternative causes for the lesions, such as dental disease, which will be discussed further below. These potential causes were noted on the recording form.

The prevalence rates were calculated according to those individuals with one or both sinuses preserved and by the number of sinuses examined for the total population, and for subsamples of the population. The sub samples are males and possible males pooled, females and possible females pooled, and three age groups, young adult, middle adult and old adult.

The total sample studied was also assessed according to the segment of the population with dental disease, and the segment of the population without any dental disease to determine the prevalence rates for these groups, in order to establish whether this is significantly more likely to be found with sinusitis (see Section 2.1.2). The prevalence of sinusitis only in individuals with dental disease was calculated for comparison. These were again calculated as number of individuals affected and the number of sinuses affected. Within the time periods studied chi-squared tests, or in instances where the number of expected individuals in a sub group is below five, fisher's exact tests, were used to determine the statistical significance of the differences between populations in that period, as well as between the sub groups described above. At the end of this section other data are given, including a statistical comparison of all 12 samples in this study using chi-squared tests, a comparison of the prevalence of bilateral and unilateral cases of sinusitis, the prevalence of each type of sinusitis as defined by Boocock *et al* (1995), and the relationship between dental disease and sinusitis.

4.2.4 Rib periostitis

In the individuals selected for this study, any available ribs or rib fragments were analysed for bone formation or pitting on the visceral surface. The preservation of the ribs was recorded as the equivalent six or less ribs (25%), between 7-18 ribs (25-50%) and 19-24 ribs (75%). Where possible the rib affected was identified and recorded. The type of bone formation was recorded as either lamellar (see Figure 4.12), which would suggest the inflammation had subsided some time before death, but not long enough before for the lesions to have remodelled completely, or woven (see Figure 4.13) suggesting that the inflammation was active at the time of death or shortly before. The general location on the rib (head, shaft, or sternal end) was also recorded. In cases where the bone remodelling was associated with another cause, either a rib fracture or remodelling on the dorsal side of the rib, this was recorded. Although the lesions may have predated the fracture, these were not included as the fracture was more likely the cause.

Figure 4.8: Rib shaft with lamellar bone representative of rib periostitis, suggesting that inflammation was no longer occurring when the individual died. Lesion is indicated with arrow

Figure 4.9: Shaft of a rib with woven bone on the visceral side, suggesting that the inflammation was active at the time of death, or shortly before. Lesions is indicated with arrow

Rib periostitis can be attributed to several forms of lower respiratory disease (see Section 2.1.3) (Molto 1990), as well as other causes such as fracture. In individuals who had rib periostitis, the rest of the skeleton was analysed in order to determine whether there were lesions that could be pathognomonic of other conditions, such as tuberculosis and brucellosis, or macroscopic evidence of healing fractures. Pott's disease, which is pathognomonic of tuberculosis, was looked for as proof of tuberculosis. However, if this was not present, the spine and joints were examined for lesions that could be indicative of tuberculosis, as well as other respiratory conditions including brucelloisis. (Ortner 2003; Roberts and Buikstra 2003).

4.2.5 Dental disease

In order to determine whether there is a significant relationship between chronic maxillary sinusitis and particular forms of severe maxillary dental disease (see Section 2.1.2), in individuals with preserved maxillae, all maxillary teeth were recorded as present or absent. Dental disease for each maxillary tooth was recorded as D, for abscesses with drainage sinuses directly into the maxilary sinuses, N, for abscesses with drainage sinuses into other parts of the maxilla (see Figure 4.10), and AMTL, for ante mortem tooth loss (see Figure 4.11). In some cases the roots of the posterior maxillary teeth extend just above floor of the sinus and are covered by only a thin layer of bone. Due to the fragile nature of this bone, it is often broken post-mortem, leaving a small unremodelled hole in the sinus floor. In order to distinguish this from a drainage sinus caused by an abscess, only cases with remodelling were recorded as dental disease.

Figure 4.10: Abscess in the maxilla with the drainage sinus opening superiorly into the maxillary sinus (left) and laterally (buccally) (right)

Figure 4.11: Ante mortem tooth loss of premolars and molars in the left half of the maxilla

4.2.6 Statistics

4.2.6.1 Summary data

Data was originally recorded by hand on recording forms (see Figure 4.12). The data was then entered into Microsoft Access 2007. Using this database, true prevalence rates were recorded for each site. True prevalence rates (TPR) are the number of elements affected as a proportion of the elements preserved and recorded. In some cases, for comparison, crude prevalence rates (CPR) were also recorded. These rates were the number of elements or

PhD Thesis Recording Form Karen Bernofsky

Site:______________________ Skeleton Number:______________

Preservation	>75	75-25	<25

Sex Estimation:	Male	?Male	Ambig.	Female	?Female	Indet.
Skull						
Pelvis						
Long Bones- Metric						

Age Estimation:	<20	20-34	35-49	>50	Ambig.	Indet
Dental Eruption						
Dental Attrition						
Suture Closure						
Pubic Symphysis						
Pelvic Auricular Surface						
Sternal end of 4th rib						

Maxillary Sinusitis:

Left		Right	
Present	Absent	Present	Absent
Description:		Description:	
Pitting	Spicule-type	Pitting	Spicule-type
Remodelled Spicules	White Pitted	Remodelled Spicules	White Pitted
Pres 1 2 3		Pres 1 2 3	
Photo Number(s):		Photo Number(s):	

Maxillary Dental Disease:

D- Direct contact N- Not in Contact A- Absent M- Missing

8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8

Pres 1 2 3

Photo Number(s)

Inflammatory Rib Lesions:

Lesions *Present*

Rib #/ Side	Description	H	S	ST	W	L	Photo #

Lesions *Absent*

Other Comments

Figure 4.12: Two page recording form used during original analysis of samples

individuals affected by the lesion of the total number of individuals available for analysis from the same population. This type of prevalence rate is more problematic as it does not account for the preservation of the particular element. In this case the total number of individuals may be significantly higher than the number of individuals who had the element preserved and this would artificially lower the prevalence rate. However, CPRs were calculated to compare to other studies for which only CPRs were stated. This was preferable to no comparison at all.

For chronic maxillary sinusitis the TPR was recorded as the number of individuals with sinusitis in one or both sinuses as a percentage of the total number of individuals with one or both sinuses. The data were also recorded as the number of sinuses with sinusitis as a percentage of the total number of sinuses analysed. In order to limit the effects of dental disease, any individuals who had abscesses or ante mortem tooth loss in the maxilla were removed and two TPRs were calculated in the same way that was described above for the subsample. TPRs were also calculated for subsamples of both the total sample and subsamples of the sample without dental disease including all of the age and sex groups defined in this study. Further, the TPRs amongst individuals with dental disease were calculated in order to determine statistical significance of the difference in the prevalence of sinusitis between individuals with and without dental disease.

Due to the poor preservation and fragmentary nature of the ribs, particularly in the earliest periods, the prevalence rate was calculated as the number of individuals with rib periostitis on at least one of the ribs as a percentage of the number of individuals with at least one rib preserved. Prevalence rates were also calculated for subsamples including all of the age and sex groups defined in this study.

4.2.6.2 Comparisons

Statistical tests carried out using SPSS 16 were used in order to determine if the differences between the populations and subsamples of the populations, including age and sex, are signficantly different. Chi-squared tests were used in most cases (Field 2005). These are presented as [$x^2(1)=$,p=]. Fisher's exact tests were used where any of the expected values were below five (Field 2005). These results as presented as [p=]. Spearman's rho test was used to compare the prevalences of sinusitis with the prevalence of rib lesions and determine whether there is any correlation. In order to determine the extent of the difference between two samples odds ratios were used in some instances (Field 2005).

4.3 Summary

This chapter has discussed the materials that will be recorded and the methods by which they will be recorded. The next chapter will present the data recorded using these materials and methods as well the results of the statistical analysis of this data.

5 Results

5.1 Introduction

The first section gives the prevalence rates for chronic maxillary sinusitis with each sample arranged chronologically, as well as the prevalence rates in relation to dental disease and types of lesions.

The next section includes a similar analysis of the prevalence of rib periostitis. The prevalence rates for each sample are presented chronologically. At the end of this section further prevalence rates and statistical tests are given in order to illuminate any patterns in the location of lesions in the rib cage and on an individual rib, as well as whether the lesions were active or healing at the time of death.

5.2 Prevalence of chronic maxillary sinusitis

For each of the sites the true prevalence of sinusitis was calculated for each population and then for each of the individual age and sex groups. The total sample, which included individuals whose age and/or sex was indeterminate, is given at the bottom of each table. These numbers were calculated in two ways, first as the number of individuals with sinusitis in at least one sinus, of the total number of individuals with at least one sinus preserved, and second as the number of sinuses with sinusitis of the total number of sinuses analysed. The individuals with visible dental abscesses and or ante mortem tooth loss in the maxilla were then removed from this total sample and a second sub sample was created. The prevalence for sinusitis amongst this subsample was then calculated using the same methods, by age and sex groups, by individual and then by sinus. The individuals who were removed made up a third subsample of individuals with dental disease, which was compared to the sample without dental disease to determine whether this had a statistically significant relationship with sinusitis in that population.

At the end of the sections, for each time period, the difference in frequency between the samples from within that period was calculated using chi-squared tests, and for any small samples with an expected frequency of 5 or less, fisher's exact tests. Comparisons are then made between all of the sites using chi-squared tests and, if necessary, fisher's exact test.

Comparisons were also made between the types of sinusitis, the relationship between sinusitis and dental disease, and the prevalence of unilateral and bilateral cases of sinusitis.

A total of 1203 individuals were examined for this study. Of these, 1101 had at least one sinus preserved, and of these individuals, 546 (49.6%) had sinusitis in one or both sinuses. A total of 2091 sinuses were recorded. Of these, 854 (40.8%) had chronic maxillary sinusitis.

5.2.1 Iron Age

As described in Chapter 5, the Iron Age sample was composed of a combination of seven sites. Table 5.1 gives the number of individuals and sinuses analysed for each of the individual populations as well as the prevalence rates. Tables 5.2 and 5.3 give the prevalence rates for the total combined sample and the total sample when individuals with dental disease are removed. Table 5.4 gives the prevalence calculated per individual and per sinus for the sub group made up of only individuals with dental disease.

	N	n	%	N*	n*	%
Danebury	12	11	**91.7**	22	19	**86.4**
Folly Lane	3	2	**66.7**	6	4	**66.7**
Micheldever Wood	2	2	**100**	4	4	**100**
Mill Hill, Deal	14	9	**64.3**	21	13	**61.9**
Suddern Farm	11	7	**63.6**	20	11	**55**
Winnall Down	2	2	**100**	4	4	**100**
Yarnton	13	10	**76.9**	22	15	**68.2**
Total	57	43	**75.44**	99	70	**70.7**

Table 5.1: The prevalence rate for chronic maxillary sinusitis in each of the individual populations- N= the total number of individuals with one or more sinus preserved, n= the total number of individuals with one or both sinuses preserved, with sinusitis in one or both sinuses. N*= the number of sinuses preserved, n*= the number of sinuses with sinusitis

	N	n	%	N*	n*	%
Male	32	27	**84.4**	58	46	**79.3**
Female	21	14	**66.7**	35	22	**62.8**
Young Adult	25	20	**68**	45	34	**75.5**
Middle Adult	23	17	**73.9**	42	27	**64.3**
Old Adult	2	2	**100**	2	2	**100**
Total	57	43	**75.44**	99	70	**70.7**

Table 5.2: Prevalence of sinusitis by age and sex in the Iron Age sample- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	13	11	**84.6**	24	19	**79.2**
Female	11	6	**54.5**	17	10	**58.8**
Young Adult	16	12	**75**	28	21	**75**
Middle Adult	6	3	**50**	11	6	**54.5**
Old Adult	1	1	**100**	1	1	**100**
Total	26	17	**65.4**	57	38	**66.7**

Table 5.3: Prevalence of sinusitis by age and sex in the Iron Age sample when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The prevalence of sinusitis in the total population is not significantly different from the prevalence amongst the proportion of the population without dental disease when calculated per person [$\chi^2(1)=0.901$, $p=0.343$] or per sinus [$\chi^2(1)=0.051$, $p=0.822$] . When the sub sample with no dental disease is compared against the proportion only made up of individuals with dental disease the results are not significant when calculated per person [$\chi^2(1)=0.37$, $p=0.543$] or per sinus [$\chi^2(1)=0.18$, $p=0.671$].

	N	n	%	N*	n*	%
Male	19	16	**84.2**	34	27	**79.4**
Female	10	8	**80**	18	12	**66.7**
Young Adult	9	8	**88.9**	17	13	**76.5**
Middle Adult	17	14	**82.3**	31	21	**67.7**
Old Adult	1	1	**100**	1	1	**100**
Total	31	26	**83.9**	42	32	**76.2**

Table 5.4: Prevalence of sinusitis in the Iron Age sample when only individuals with dental disease are included*- N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between males and females in the population was not significant when calculated per person [p=0.183] or sinus [χ^2(1)=3.006, p=0.83]. The difference in prevalence was not significant between the young and middle adults [χ^2 (1)=0.251, p=0.616], young and old adults [p=1], or middle and old adults [p=1].

5.2.2 Roman Period

5.2.2.1 Lankhills

Tables 5.5, 5.6 and 5.7 give the prevalence rates for the total sample and the adjusted samples when individuals with dental disease are removed, and when only the individuals with dental disease are included. At Lankhills, the difference between the total population and the sample without dental disease is not significant when comparing the prevalence per person [χ^2(1)=2.579, p=0.108] or per sinus [χ^2(1)=3.167, p=0.075]. When the population with dental disease is compared with only the individuals who had dental disease the result was not significant when calculated per person [χ^2(1)=3.705, p=0.054] or per sinus [χ^2(1)=3.568, p=0.059]. The difference between the prevalence amongst males and females at this site was not significant when calculated per person [χ^2(1)=0.267, p=0.606] or per sinus [χ^2(1)=1.981, p=0.159]. The difference between the prevalence rates for the young and middle age individuals [p=0.188] and middle and old age individuals [p=0.084] were not significant. The difference between the prevalence for the young and old adults was significant [p=0.01]

	N	n	%	N*	n*	%
Male	45	15	**33.3**	87	22	**25.3**
Female	28	11	**39.3**	52	19	**36.5**
Young Adult	14	2	**14.3**	28	4	**14.3**
Middle Adult	45	17	**37.8**	87	26	**29.9**
Old Adult	10	7	**70**	19	11	**57.9**
Total	74	26	**35.1**	141	41	**29.1**

Table 5.5: Prevalence of sinusitis by age and sex at Lankhills- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	22	5	**22.7**	43	8	**18.6**
Female	14	2	**14.3**	25	4	**16**
Young Adult	13	2	**15.4**	23	4	**17.4**
Middle Adult	21	5	**23.8**	41	8	**19.5**
Old Adult	0	0	**0**	0	0	**0**
Total	36	7	**19.4**	82	17	**20.7**

Table 5.6: Prevalence of sinusitis by age and sex for Lankhills when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	23	10	**43.5**	44	14	**31.8**
Female	14	9	**64.3**	27	15	**55.6**
Young Adult	1	0	**0**	3	0	**0**
Middle Adult	24	12	**50**	46	18	**39.13**
Old Adult	10	7	**70**	19	11	**57.9**
Total	38	19	**50**	59	24	**40.7**

Table 5.7: Prevalence of sinusitis for Lankhills when only individuals with dental disease are included- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

5.2.2.2 Roman London

The individuals from the two Roman skeletal populations come from a number of excavations outside the eastern and western walls of Roman London. As these sites individually included too few individuals, the prevalence rates for the combined eastern and western Roman cemeteries are given in Table 5.8. Tables 5.9, 5.10, and 5.11 give the prevalence rates for the total combined sample and the subsamples only including individuals without dental disease, and only individuals with dental disease.

	N	n	%	N*	n*	%
Eastern Cemetery	68	21	**30.9**	127	30	**23.6**
Western Cemetery	20	7	**35**	36	11	**30.5**
Total	88	28	**31.8**	163	41	**25.1**

Table 5.8: The prevalence of sinusitis within the Eastern and Western Roman cemeteries that make up the combined Roman London sample- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	63	21	**33.3**	116	30	**25.9**
Female	23	7	**30.4**	44	12	**27.3**
Young Adult	25	8	**32**	47	12	**25.5**
Middle Adult	57	16	**28.1**	106	24	**22.6**
Old Adult	6	4	**66.7**	10	5	**50**
Total	88	28	**31.8**	163	41	**25.1**

Table 5.9: Prevalence of sinusitis by age and sex in the sample from Roman London- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	33	8	**24.2**	61	11	**18**
Female	16	5	**31.2**	31	8	**25.8**
Young Adult	20	4	**20**	37	6	**16.2**
Middle Adult	29	8	**27.6**	54	12	**22.2**
Old Adult	1	1	**100**	2	1	**50**
Total	51	13	**25.5**	114	25	**21.9**

Table 5.10: Prevalence of sinusitis by age and sex in the sample from Roman London without any dental disease- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the two populations from Roman London is not statistically significant if calculated per person [$\chi^2(1)=0.061, p= 0.804$], or per sinus [$\chi^2(1)=0.716$ $p= 0.397$]. The difference between the prevalence in the total sample and the sample without dental disease is not significant when calculated per person [$\chi^2(1)=0.343, p=0.558$] or per sinus [$\chi^2(1)=0.237$, $p=0.626$].

	N	n	%	N*	n*	%
Male	30	13	**43.3**	55	19	**34.5**
Female	7	2	**28.6**	13	4	**30.8**
Young Adult	5	4	**80**	10	6	**60**
Middle Adult	28	8	**28.6**	52	12	**23.1**
Old Adult	5	3	**60**	8	4	**50**
Total	37	15	**40.5**	49	16	**32.6**

Table 5.11: Prevalence of sinusitis in individuals with dental disease for the sample from Roman London- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

When the population with no dental disease is compared with the population made up of only individuals with dental disease the results are not significant when calculated per person [$\chi^2(1)=1.141$, p=0.285] or per sinus [$\chi^2(1)=1.212$, p=0.271]. The difference between males and females from Roman London is not statistically significant when calculated per person [$\chi^2(1)=0.064$,p=0.8] or per sinus [$\chi^2(1)=0.033$,p=0.856]. The differences between the age groups in this sample were not statistically significant [$\chi^2(1)=0.13$, p=0.719], [p=0.174], [p=0.075].

5.2.2.3 Comparison

The difference between the two populations from the Roman Period is not statistically significant when calculated per person [$\chi^2(1)=0.099$, p= 0.753] or per sinus [$\chi^2(1)=0.339$, p=0.56]. The difference remains statistically insignificant when only individuals without dental disease are included when calculated per person [$\chi^2(1)=0.275$, p=0.6] and per sinus [$\chi^2(1)=0.026$, p=0.871].

5.2.3 Early Medieval

5.2.3.1 Cannington

The prevalence rates for sinusitis in the total sample from Cannington, as well as for the age and sex groups, are given in Table 5.12. Table 5.13 gives the prevalence rates when individuals with dental disease are removed from the sample and Table 5.14 gives the prevalence in the sample only made up of individuals with dental disease.

	N	n	%	N*	n*	%
Male	77	42	**53.85**	156	62	**39.74**
Female	54	24	**44.44**	108	33	**30.56**
Young Adult	20	9	**45**	36	11	**30.55**
Middle Adult	103	51	**49.51**	192	75	**39.1**
Old Adult	7	6	**85.71**	10	8	**80**
Total	131	63	**48.1**	244	95	**38.9**

Table 5.12- Prevalence of sinusitis by age and sex in the sample from Cannington*- Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	52	25	**48.08**	96	37	**38.54**
Female	39	15	**38.46**	66	20	**30.30**
Young Adult	19	8	**42.10**	34	10	**29.41**
Middle Adult	66	29	**43.93**	121	40	**33.06**
Old Adult	4	3	**75**	5	4	**80**
Total	89	40	**44.5**	183	63	**34.4**

Table 5.13: Prevalence of sinusitis by age and sex from Cannington when individuals with dental disease are removed from the sample - *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Males	26	17	**65.4**	60	25	**41.7**
Females	15	9	**60**	42	13	**30.9**
Young Adult	1	1	**100**	2	1	**50**
Middle Adult	37	22	**59.46**	71	35	**49.3**
Old Adult	3	3	**100**	5	4	**80**
Total	42	23	**54.8**	61	32	**52.5**

Table 5.14: Prevalence of sinusitis from Cannington when only individuals with dental disease are included- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the total population from Cannington and the sample not including individuals with dental disease is not statistically significant when calculated per person [$\chi^2(1)=0.077$, $p=0.782$] or per sinus [$\chi^2(1)=0.421$, $p=0.516$]. When the population without any dental disease is compared to the segment of the population with dental disease the result is not significant when calculated per person [$\chi^2(1)=0.378$, $p=0.539$] or per sinus [$\chi^2(1)=2.59$, $p=0.108$]. The difference between the prevalence in males and females was not statistically significant when calculated per person [$\chi^2(1)=1.128$, $p=0.288$] or per sinus [$\chi^2(1)=2.339$, $p=0.126$]. The differences between the age groups are not significant (young and middle age Groups [$\chi^2(1)=0.137$, $p=0.712$], Young and Old Age Groups [$p=0.091$] Middle and old age groups [$p=0.115$]).

5.2.3.2 Southeast combined sample (Edix Hill/Staunch Meadow)

The prevalence rates for sinusitis in the two Early Medieval populations from the Southeast are given below in Table 5.15. These sites are also combined into a single sample for comparison to Cannington. The prevalence rates for the age and sex groups and total sample are given in Table 5.16. Table 5.17 gives the prevalence rates when individuals with dental disease are removed from the sample, and Table 5.18 gives the prevalence of sinusitis in the subsample that only includes individuals with dental disease.

	N	n	%	N*	n*	%
Edix Hill	39	21	**53.8**	77	30	**39**
Staunch Meadow	16	5	**31.2**	29	7	**24.1**
Total	55	26	**47.3**	106	37	**34.9**

Table 5.15 The prevalence of sinusitis at the individual sites that make up the Early Medieval combined sample- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	32	15	**46.9**	62	23	**37.1**
Female	21	11	**52.4**	39	15	**38.5**
Young Adult	15	8	**53.3**	28	14	**50**
Middle Adult	38	17	**44.7**	74	23	**31.08**
Old Adult	0	0	**0**	0	0	**0**
Total	55	26	**47.3**	106	37	**34.9**

Table 5.16- Prevalence of sinusitis by age and sex in the Early Medieval Southeastern sample- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between Edix Hill and Staunch Meadow is not statistically significant when calculated per person [$\chi^2(1)=2.313$, p=0.128] or per sinus [$\chi^2(1)=2.047$, p=0.152]. The difference between the total sample and those without dental disease from the Early Medieval combined sample is not statistically significant when calculated per person [$\chi^2(1)=0.360$, p=0.548] or per sinus [$\chi^2(1)=0.123$, p=0.726]. When the population with no dental disease is compared against the part of the population with dental disease the result is not significant when calculated per individual [$\chi^2(1)=0.382$, p=0.537] or per sinus [$\chi^2(1)=0.968$, p=0.325]. The difference between the males and females at the site was not significant when calculated per person [$\chi^2(1)=0.154$, p=0.685] or per sinus [$\chi^2(1)=0.019$, p=0.89]. The difference between the young adults and middle adults was not significant [$\chi^2(1)=0.319$, p=0.572].

	N	n	%	N*	n*	%
Male	24	10	**41.7**	46	16	**34.8**
Female	12	6	**50**	24	9	**37.5**
Young Adult	13	6	**46.1**	24	10	**41.7**
Middle Adult	24	9	**37.5**	47	13	**27.7**
Old Adult	0	0	**0**	0	0	**0**
Total	39	16	**41.03**	89	28	**31.46**

Table 5.17: Prevalence of sinusitis by age and sex in the combined Southeastern Early Medieval sample when only individuals without dental disease are included - *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	8	5	**62.5**	16	7	**43.75**
Female	9	5	**55.6**	15	6	**40**
Young Adult	2	2	**100**	4	4	**100**
Middle Adult	14	8	**57.14**	27	10	**37.04**
Old Adult	0	0	**0**	0	0	**0**
Total	16	10	**62.5**	17	9	**52.9**

Table 5.18: Prevalence of sinusitis in the Southeastern Early Medieval combined sample when only individuals with dental disease are included- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

5.2.3.3 Comparison

The difference between the two populations from the Early Medieval Period is not statistically significant when calculated per person [χ^2 (1)=0.01, p=0.919] or per sinus [χ^2 (1)=0.299, p=0.585]. The difference is still not significantly different when calculated per person [χ^2 (1)=0.129, p=0.719] and per sinus [χ^2 (1)=0.061, p=0.805] when individuals with dental disease are removed from the samples

5.2.4 Late Medieval

5.2.4.1 Abingdon Vineyard

Table 5.19 gives the prevalence rates for the total population from Abingdon Vineyard as well as for the individual age and sex groups from the site. Table 5.20 gives these prevalence rates when individuals with dental disease are removed from the sample and Table 5.21 gives the prevalence when only individuals with dental disease are included.

	N	**n**	**%**	**N***	**n***	**%**
Male	90	59	**65.5**	168	104	**61.9**
Female	51	33	**64.7**	93	59	**63.4**
Young Adult	45	29	**64.4**	83	51	**61.4**
Middle Adult	83	58	**69.9**	155	103	**66.4**
Old Adult	11	5	**45.4**	19	9	**47.4**
Total	142	95	**66.9**	267	169	**63.3**

Table 5.19- Prevalence of sinusitis by age and sex in the sample from Abingdon Vineyard- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the prevalence for the total population and the population that excludes individuals with dental disease at Abingdon is not statistically significant when calculated per person [χ^2(1)=0.588, p=0.443], or when calculated per sinus [x^2(1)=0.507, p=0.476]. When the population with no dental disease is compared to the population with dental disease the results were not significant when calculated per individual [χ^2(1)=1.445, p=0.229] or per sinus [χ^2(1)=1.72, p=0.19]. The difference in the prevalence amongst males and females is not statistically significantly different when calculated per person [χ^2(1)=0.01, p=0.919] or per sinus [χ^2(1)=0.06, p=0.806]. The differences between the age groups were not significant (young and middle age groups[$\chi^2(1)$=0.396, p= 0.529] young and old age groups [p=0.31] middle and old age groups [p=0.169]).

	N	n	%	N*	n*	%
Male	42	24	**57.1**	77	40	**51.9**
Female	22	12	**54.5**	37	21	**56.8**
Young Adult	29	17	**58.6**	51	29	**56.9**
Middle Adult	33	18	**54.5**	63	32	**50.8**
Old Adult	2	1	**50**	4	2	**50**
Total	65	36	**55.4**	153	86	**56.2**

Table 5.20: Prevalence of sinusitis by age and sex from Abingdon Vineyard when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	48	35	**72.9**	91	64	**70.33**
Female	29	21	**72.4**	56	38	**67.86**
Young Adult	16	12	**75**	32	22	**68.75**
Middle Adult	50	40	**80**	92	71	**77.2**
Old Adult	9	4	**44.4**	15	7	**46.7**
Total	77	59	**76.6**	114	83	**72.8**

Table 5.21: Prevalence of sinusitis from Abingdon Vineyard when only individuals with dental disease are included- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

5.2.4.2 Merton Priory

Table 5.22 gives the prevalence rates for sinusitis in the total sample from Merton Priory. Table 5.23 gives the prevalence rates for the sample when individuals with dental disease are removed and Table 5.24 gives the prevalence of sinusitis in only the individuals with dental disease.

	N	n	%	N*	n*	%
Male	96	53	**55.2**	187	84	**44.9**
Female	7	5	**71.4**	14	11	**78.6**
Young Adult	11	6	**54.5**	21	9	**42.9**
Middle Adult	74	40	**54**	145	66	**45.5**
Old Adult	18	12	**66.7**	35	17	**48.6**
Total	103	58	**56.3**	201	92	**45.8**

Table 5.22: Prevalence of sinusitis by age and sex in the sample from Merton Priory-*Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	57	27	**47.4**	112	44	**39.3**
Female	5	4	**80**	10	9	**70**
Young Adult	8	4	**50**	15	6	**40**
Middle Adult	46	23	**53.5**	91	40	**44**
Old Adult	8	4	**50**	16	5	**31.2**
Total	62	31	**50**	140	56	**40**

Table 5.23: Prevalence of sinusitis by age and sex from Merton Priory when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	39	26	**66.7**	75	40	**53.3**
Female	2	1	**50**	4	2	**50**
Young Adult	3	2	**66.7**	6	3	**50**
Middle Adult	28	17	**60.7**	54	26	**48.15**
Old Adult	10	8	**80**	19	12	**63.16**
Total	41	27	**65.8**	61	36	**59**

Table 5.24: Prevalence of sinusitis in the sample from Merton Priory when only individuals with dental disease are included- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

At Merton Priory the difference between the total sample and the sample not including individuals with dental disease is not significant when calculated per person [$\chi^2(1)=0.62$, $p=0.431$] or per sinus [$\chi^2(1)=0.445$, $p=0.505$]. When the prevalence for the population with dental disease is compared to the population with dental disease the difference is not significant when calculated per person [$\chi^2(1)=0.509$, $p=0.476$] or per sinus [$\chi^2(1)=2.198$, $p=0.138$]. The results of the chi-squared tests and fisher's exact test found that the difference between the males and the five females in the sample is not significant ($p=0.464$) or between the age groups were not significant (young and middle age groups [$\chi^2(1)=0.001$, $p=0.976$] young and old age groups [$p=0.696$] middle and old age groups [$\chi^2(1)=0.937$, $p=0.333$]).

5.2.4.3 St. Mary Graces

Table 5.25 gives the prevalence of sinusitis in the total sample from St. Mary Graces. Table 5.26 gives the prevalence for the sample when the individuals with dental disease are removed from the sample and Table 5.27 gives the prevalence for only the segment of the population that has dental disease.

	N	n	%	N*	n*	%
Male	56	37	**66.1**	97	55	**56.7**
Female	22	9	**40.9**	42	13	**30.9**
Young Adult	34	7	**20.6**	59	27	**45.8**
Middle Adult	37	22	**59.5**	67	31	**46.3**
Old Adult	7	6	**85.7**	13	9	**69.2**
Total	78	46	**59**	139	67	**48.2**

Table 5.25: Prevalence of sinusitis by age and sex in the sample from St. Mary Graces- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	23	13	**56.2**	36	19	**52.8**
Female	15	7	**46.7**	28	9	**32.1**
Young Adult	18	7	**38.9**	29	9	**31**
Middle Adult	19	12	**63.2**	34	18	**52.9**
Old Adult	1	1	**100**	2	1	**50**
Total	40	20	**50**	85	34	**40%**

Table 5.26: Prevalence of sinusitis by age and sex in the sample from St. Mary Graces when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

At St. Mary Graces the difference between the total sample and the sample not including individuals with dental disease is not significant when calculated per person [$\chi^2(1)=0.249$, p=0.618] or per sinus [$\chi^2(1)=0.550$, p=0.458]. When the sample without dental disease is compared against the sample with dental disease the results are not significant when calculated per person [$\chi^2(1)=0.706$, p=0.401] or per sinus [$\chi^2(1)=2.006$, p=0.157].

	N	n	%	N*	n*	%
Male	33	24	**72.7**	61	36	**59**
Female	7	2	**28.6**	14	4	**28.6**
Young Adult	16	0	**0**	30	18	**60**
Middle Adult	18	10	**55.6**	33	13	**39.4**
Old Adult	6	5	**83.3**	11	8	**72.7**
Total	38	26	**68.4**	54	33	**61.1**

Prevalence of sinusitis in the sample from St. Mary Graces when only individuals with dental disease are included- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the males and females from St. Mary Graces is statistically significant when calculated per person [$\chi^2(1)=4.133$, p=0.042] and per sinus [$\chi^2(1)=7.776$, p=0.005]. The difference between the young adults and middle adults [$\chi^2(1)=12.647$, p=<0.001], and the young adults and old adults [p=0.002] were both statistically significant. The difference between middle and old age groups were not statistically significant [p=0.392].

5.2.4.4 Urban, Low Status combined sample

	N	n	%	N*	n*	%
St. Nicholas Shambles	20	12	**60**	36	19	**52.7**
Guildhall Yard East	20	8	**40**	40	13	**32.5**
Total	40	20	**50**	76	32	**42.1**

Table 5.27: The prevalence of sinusitis and the individual sites that make up the Urban Low Status Late Medieval combined sample- *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

Table 5.27 gives the prevalence of sinusitis in the individual sites that make up the low status urban group. Table 5.28 gives the prevalence of sinusitis in the total combined sample Table 5.29 gives the prevalence in the combined sample when individuals with dental disease are removed from the sample, and Table 5.30 gives the prevalence in the population with dental disease.

	N	n	%	N*	n*	%
Male	27	13	**48.1**	51	19	**37.2**
Female	11	7	**63.6**	21	13	**61.9**
Young Adult	9	3	**33.3**	18	6	**33.3**
Middle Adult	29	15	**51.7**	54	24	**44.4**
Old Adult	2	2	**100**	4	2	**50**
Total	40	20	**50**	76	32	**42.1**

Table 5.28: Prevalence of sinusitis by age and sex in the Late Medieval Low Status urban sample- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	18	8	**44.4**	35	12	**34.3**
Female	9	7	**77.8**	17	13	**76.5**
Young Adult	9	3	**33.3**	18	6	**33.3**
Middle Adult	19	10	**52.6**	36	17	**47.2**
Old Adult	2	2	**100**	4	2	**50**
Total	30	15	**50**	62	27	**43.5**

Table 5.29: Prevalence of sinusitis by age and sex in the combined Late Medieval Low Status urban Sample- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	9	5	**55.5**	16	7	**43.75**
Female	2	0	**0**	4	0	**0**
Young Adult	0	0	**0**	0	0	**0**
Middle Adult	10	5	**50**	18	7	**38.9**
Old Adult	0	0	**0**	0	0	**0**
Total	10	5	**50**	14	5	**35.7**

Table 5.30: Prevalence of sinusitis in the combined Low Status Urban Late Medieval Sample in only individuals with dental disease - *N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

When the prevalence rates for St. Nicholas Shambles and Guildhall Yard East are compared the difference between them is not significant when calculated per individual [$\chi^2(1)=0.536$, p=0.464] or per sinus [$\chi^2(1)=1.299$, p=0.254]. In the combined low status urban sample the difference between the total sample and the sample not including individuals with dental disease is not significant when calculated per person [$\chi^2(1)=0.000$, p=1.00] or per sinus [$\chi^2(1)=0.012$, p=0.914]. When the difference between the prevalence in individuals without dental disease and with dental disease are compared, the differences are not significant when calculated per individual [$\chi^2(1)=0.000$, p=1.00] or per sinus [$\chi^2(1)=0.121$, p=0.727]. The difference between the males and females in the combined low status urban sample is not statistically significant when calculated per person [$\chi^2(1)=0.752$, p=0.386] or per sinus [$\chi^2(1)=3.661$, p=0.056]. However, the latter is nearly significant. The difference between the age groups was not significant (young adult and middle adult age groups [p=0.454] young adult and old adult age groups [p=0.182] middle adult and old adult age groups [p=0.488]).

5.2.4.5 Comparison

Table 5.31 shows the chi-squared number to determine the statistical significance of the difference between each of the populations from the Late Medieval Period. The left half of the table gives the difference between the prevalence when calculated per person and the right half, in grey, shows the difference when calculated per sinus. Chi-squared results that are significant at 5% are shown in red.

X^2=	Abingdon	St. Mary Graces	Merton Priory	Combined low urban
Abingdon		2.341	4.123	3.098
St. Mary Graces	0.305		0.071	0.275
Merton Priory	0.668	0.129		0.116
Combined urban low	0.92	0.864	0.463	

Table 5.31: The results of chi-squared tests to determine the statistical significance of the difference between the four late medieval samples- Significant results(p=0.05 and 1 degree of freedom) shown in red

Table 5.32 shows the chi-squared results in order to determine the statistical significance of the difference between each of the populations from the Late Medieval Period when the individuals with dental disease are removed from the sample. The left half of the table gives the difference between the prevalence when calculated per person and the right half, in grey, shows the difference when calculated per sinus. None of the differences were significant at p=0.05 and 1 degree of freedom.

X^2=	Abingdon	St. Mary Graces	Merton Priory	Combined low urban
Abingdon		0.587	2.691	0.915
St. Mary Graces	0.275		0.000	0.077
Merton Priory	0.114	0.000		0.092
Combined urban low	0.089	0.000	0.000	

Table 5.32: The results of chi-squared tests to determine the statistical significance of the differences between the prevalence rates in the four late medieval samples when individuals with dental disease are removed from all samples. There were no statistically significant differences at p=0.05 and 1 degree of freedom.

5.2.5 Post Medieval

5.2.5.1 Chelsea Old Church

	N	n	%	N*	n*	%
Male	47	19	**40.4**	84	27	**32.1**
Female	30	14	**46.7**	60	20	**33.3**
Young Adult	16	9	**52.9**	32	13	**40.6**
Middle Adult	50	19	**38**	93	28	**30.1**
Old Adult	12	5	**41.7**	22	6	**27.3**
Total	78	33	**42.3**	147	47	**31.2**

Table 5.33: Prevalence of sinusitis by age and sex in the sample from Chelsea Old Church- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	13	7	**53.8**	24	10	**41.7**
Female	8	6	**75**	16	7	**43.7**
Young Adult	10	7	**70**	20	10	**50**
Middle Adult	10	4	**40**	18	5	**27.8**
Old Adult	3	2	**66.7**	5	2	**40**
Total	25	13	**52**	58	21	**36.2**

Table 5.34: Prevalence of sinusitis by age and sex in the sample from Chelsea Old Church when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	34	12	**35.3**	60	17	**28.3**
Female	22	8	**36.4**	44	13	**29.5**
Young Adult	6	2	**33.3**	12	3	**25**
Middle Adult	40	15	**37.5**	75	23	**30.67**
Old Adult	9	3	**33.3**	17	4	**23.5**
Total	53	20	**37.7**	89	26	**29.2**

Table 5.35: Prevalence of sinusitis in the sample from Chelsea Old Church when only individuals with dental disease are included*-N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

Table 5.33 shows the prevalence of sinusitis in the sample from Chelsea Old Church. Table 5.34 gives the prevalence rates when individuals without dental disease are removed from the sample, and Table 5.35 gives the prevalence rates for the samples when only individuals with dental disease are included.

The difference between the prevalence in the total sample from Chelsea Old Church and the sample excluding individuals without dental disease is not statistically significant when calculated per person [$\chi^2(1)=0.266$, p=0.606] or per sinus [$\chi^2(1)=0.167$, p=0.683]. When the prevalence in only individuals with dental disease is compared against only individuals without dental disease the difference is not significant when calculated per individual [$\chi^2(1)=0.555$, p=0.456] or per sinus [$\chi^2(1)=0.403$, p=0.526]. The prevalence rates amongst males and females in this sample are not statistically significant when calculated per person [$\chi^2(1)=0.291$, p=0.589] or per sinus [$\chi^2(1)=0.023$, p=0.881]. The differences between the age groups were not significant (young adult and middle adult age groups [$\chi^2(1)= 1.653$, p=0.199], young adult and old adult age groups [$\chi^2(1)=0.583$, p=0.445], middle adult and old adult age groups [p=1]).

5.2.5.2 St. Bride's Crypt (High Status)

Table 5.36 gives the prevalence of sinusitis in the total sample from St. Bride's Crypt. Table 5.37 gives the prevalence rates for the sample when individuals without dental disease are removed and Table 5.38 gives the prevalence rates when only individuals with dental disease are included.

	N	n	%	N*	n*	%
Male	70	22	**31.4**	138	32	**23.2**
Female	64	19	**29.7**	127	32	**25.2**
Young Adult	22	8	**36.4**	44	13	**29.5**
Middle Adult	28	7	**25**	56	11	**19.6**
Old Adult	83	26	**31.3**	163	41	**25.1**
Total	134	41	**30.6**	265	64	**24.1**

Table 5.36: Prevalence of sinusitis by age and sex in the high status sample from St. Bride's Crypt- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	18	3	**16.7**	35	5	**14.3**
Female	13	2	**15.4**	24	3	**12.5**
Young Adult	13	4	**30.8**	26	7	**26.9**
Middle Adult	8	0	**0**	16	0	**0**
Old Adult	9	1	**11.1**	17	1	**5.9**
Total	30	5	**16.7**	86	16	**18.6**

Table 5.37: Prevalence of sinusitis by age and sex in the high status sample from St. Bride's Crypt when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	52	19	**36.54**	103	27	**26.21**
Female	51	17	**33.3**	103	29	**28.15**
Young Adult	9	4	**44.4**	18	6	**33.3**
Middle Adult	20	7	**35**	40	11	**27.5**
Old Adult	74	25	**33.8**	146	40	**27.4**
Total	104	36	**34.6%**	179	48	**26.8**

Table 5.38: Prevalence of sinusitis in the high status sample from St. Bride's Crypt when only individuals with dental disease are included*- N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the prevalence for the total sample and the sample excluding individuals with dental disease at St. Bride's Crypt is not statistically significant when calculated per person [$\chi^2(1)=1.425$, $p=0.233$], or when calculated per sinus [$\chi^2(1)=0.731$, $p=0.393$]. When the prevalence of sinusitis in individuals without dental disease is compared against the prevalence in individuals with dental disease the prevalence is not significant when calculated per person [$\chi^2(1)=2.039$, $p=0.153$] or per sinus [$\chi^2(1)=1.339$, $p=0.247$]. The difference between the prevalence for males and females is not significant when calculated per person [$\chi^2(1)=0.048$, $p=0.827$] or per sinus [$\chi^2(1)=0.146$, $p=0.703$]. The difference between the age groups was not statistically significant (young adult and middle adult age groups [$\chi^2(1)=0.758$, $p=0.384$] young adult and old adult age groups [$\chi^2(1)=0.202$, $p=0.653$], middle adult and old adult age groups [$\chi^2(1)=0.401$, $p=0.527$]).

5.2.5.3 St. Bride's Lower (Low Status)

Table 5.39 gives the prevalence of sinusitis in the total sample from St. Bride's Lower. Table 6.40 gives the prevalence rates for the sample when individuals without dental disease are removed, and Table 6.41 gives the prevalence rates when only individuals with dental disease are included.

	N	n	%	N*	n*	%
Male	82	40	**48.8**	163	60	**36.8**
Female	40	24	**60**	80	38	**47.5**
Young Adult	14	8	**57.1**	28	14	**50**
Middle Adult	75	37	**49.3**	147	55	**37.4**
Old Adult	33	17	**51.5**	66	28	**42.4**
Total	122	64	**52.5**	243	99	**40.7**

Table 5.39: Prevalence of sinusitis by age and sex in the low status sample from St. Bride's Lower Crypt- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

	N	n	%	N*	n*	%
Male	11	4	**36.4**	22	5	**22.7**
Female	5	2	**40**	10	3	**30**
Young Adult	4	2	**50**	8	4	**50**
Middle Adult	12	4	**33.3**	24	4	**16.7**
Old Adult	0	0	**0**	0	0	**0**
Total	16	6	**37.5**	61	16	**26.2**

Table 5.40: Prevalence of sinusitis by age and sex in the low status sample from St. Bride's Lower when individuals with dental disease are removed- *Total includes all individuals for whom age and or sex could not be estimated. N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the total sample from St. Bride's lower and the individuals without dental disease is not significant when calculated per person [$\chi^2(1)$=1.266, p=0.26] or per sinus [$\chi^2(1)$=2.106, p=0.147]. When the prevalence of sinusitis in individuals without dental disease are compared to the prevalence in individuals with dental disease, the prevalence remains not significant when calculated per individual [$\chi^2(1)=0.563$, p=0.453] and per sinus [$\chi^2(1)=3.224$, p=0.073].

	N	n	%	N*	n*	%
Male	71	36	**50.7**	141	55	**39**
Female	35	22	**62.86**	70	35	**50**
Young Adult	10	6	**60**	20	10	**50**
Middle Adult	63	33	**52.4**	123	51	**41.5**
Old Adult	33	17	**51.5**	66	28	**42.4**
Total	106	58	**54.7%**	182	83	**45.6%**

Table 5.41: Prevalence of sinusitis in the low status sample from St. Bride's Lower when only individuals with dental disease are included*- N is the total number of individuals with one or both sinuses preserved. n is the number of individuals (N) who had sinusitis in one or both sinuses. N* is the number of sinuses preserved. n* is the number of sinuses which had sinusitis.*

The difference between the males and females in the sample is not significant when calculated per person [$\chi^2(1)=1.357$, p=0.244] or per sinus [$\chi^2(1)=2.548$, p=0.110]. The differences between the age groups were not significant (young adult and middle adult age groups [$\chi^2(1)=0.288$, p=0.592], young adult and old adult age groups [$\chi^2(1)=2.126$, p=0.145], middle adult and old adult age groups [$\chi^2(1)=2.302$, p=0.129]).

5.2.5.4 Comparison

When the populations from St. Bride's Crypt and St. Bride's Lower are compared, the difference between the prevalence rates is statistically significant when calculated per person [$\chi^2(1)=12.616$, p=<0.001] or per sinus [$\chi^2(1)=8.219$, p=0.004]. When St. Bride's Crypt is compared to Chelsea Old Church, the difference is not statistically significant when calculated per person [$\chi^2(1)=1.406$, p=0.236] or per sinus [$\chi^2(1)=1.664$, p=0.116]. When St. Bride's Lower is compared to Chelsea Old Church the difference is not statistically significant when calculated per person [$\chi^2(1)=0.692$, p=0.406] or per sinus [$\chi^2(1)=1.392$, p=0.238].

When the individuals with dental disease are removed, the difference between St. Bride's Crypt and St. Bride's Lower is no longer statistically significant when calculated per person [p=0.305] or per sinus [$\chi^2(1)=0.775$, p=0.379]. The difference between St. Bride's Crypt and Chelsea Old Church is significant when calculated per person [$\chi^2(1)=3.893$, p=0.048] but not per sinus [$\chi^2(1)=3.25$, p=0.071]. The difference between St. Bride's Lower and Chelsea Old Church is significant when calculated per person [$\chi^2(1)=0.31$, p= 0.578] and per sinus [$\chi^2(1)=0.726$, p=0.394].

5.2.5.5 Sinusitis in Southeast England: sites compared

This section will compare the prevalence rates given above for all of the samples in this study both graphically and statistically. Figures 5.1 and 5.2 show the prevalence of sinusitis in all of the samples and in all of the samples when dental disease is removed. These prevalence rates are compared graphically in Figure 5.3.

Although the previous three figures allow visual comparison of the differences in the prevalence rates of sinusitis in these twelve samples, chi-squared tests were used to determine whether these were statistically significant. These results are presented in Table 5.42.

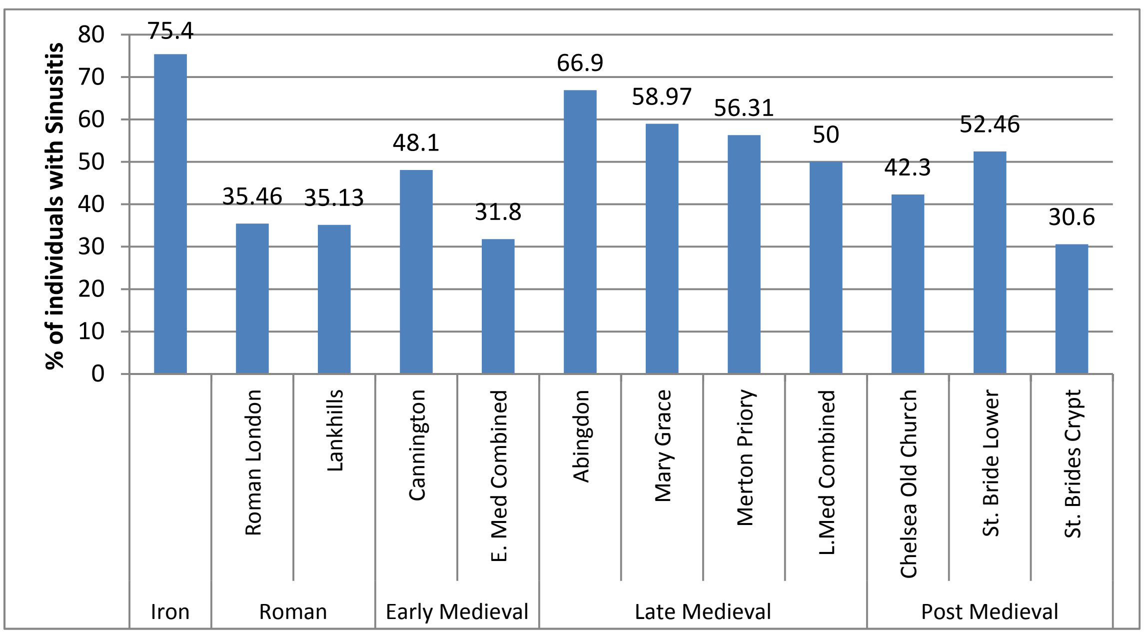


Figure 5.1: Prevalence of sinusitis – *Number of individuals with sinusitis in one or both sinuses as a percentage of the individuals with one or both sinuses preserved*

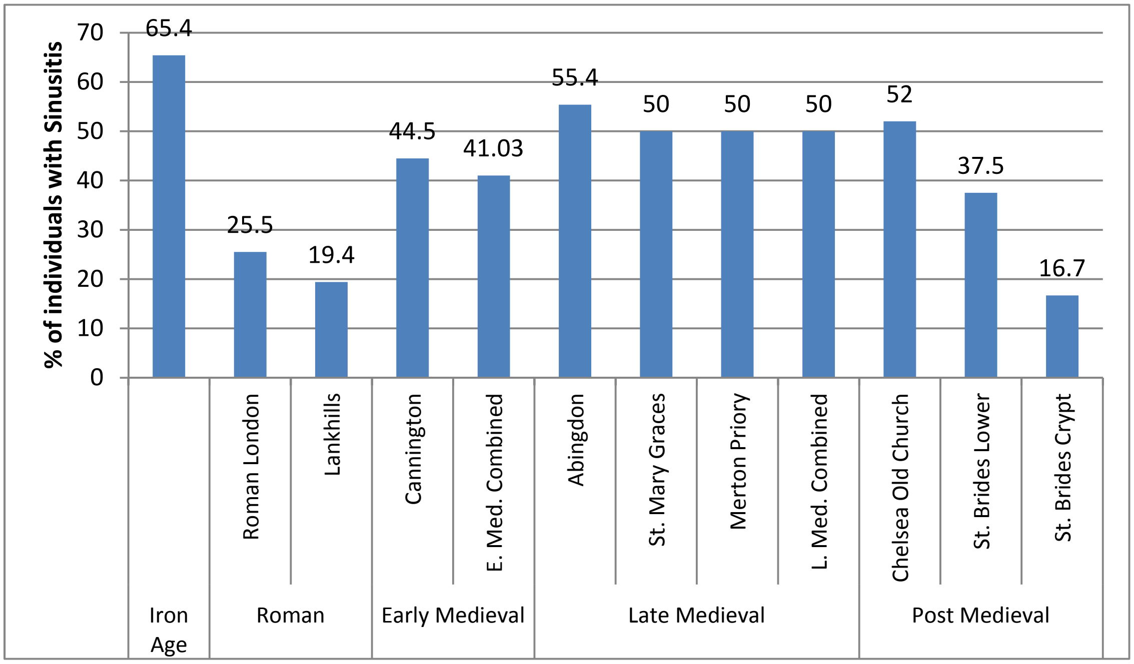


***Figure 5.2: Prevalence of sinusitis in individuals without dental disease –** number of individuals with sinusitis in one or both sinuses and no dental disease as a percentage of the number of individuals with one or both sinuses preserved and no dental disease*

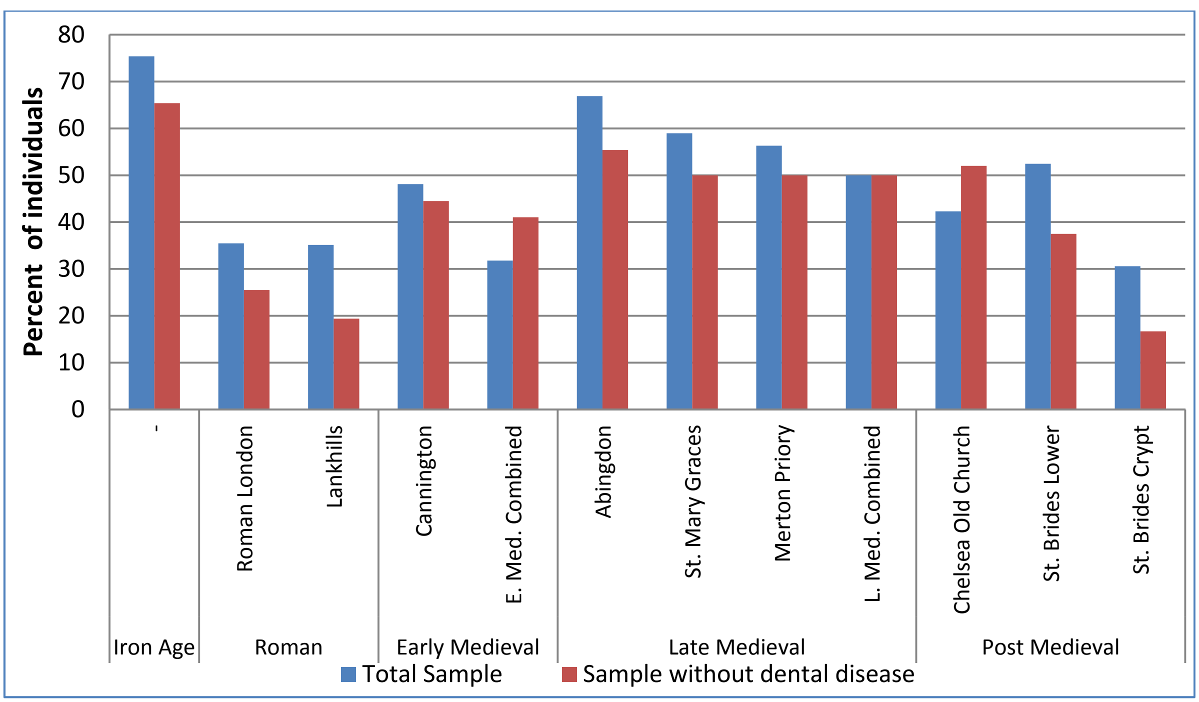


Figure 5.3: Comparison of the prevalence (%) in the total sample and the subpopulation without visible dental disease

When the chi-squared results for the populations without dental disease are compared with the chi-squared results when entire samples are used, far fewer differences are significant. They are limited to differences between the Roman populations and St. Bride's Crypt, which are the three lowest prevalence rates recorded.

X^2=	Iron Age	Lankhills	Roman London	Cannington	Early Med Combined	Abingdon Vineyard	Merton Priory	Mary Graces	Late Med. combined	Chelsea Old Church	St. Bride's Crypt	St. Bride's Lower
Iron Age		20.981	8.659	12.07	9.388	0.247	5.768	3.974	6.681	4.02	32.637	8.532
Lankhills	5.78		0.099	5.383	3.330	6.062	10.775	11.652	3.777	0.363	0.022	8.269
Roman London	4.71	0.275		2.433	1.519	8.723	4.45	4.719	1.686	0.903	0.019	3.558
Cannington	1.058	3.523	2.456		0.010	2.661	1.560	2.32	0.045	0.247	8.53	0.482
Early Med. Combined	1.179	2.205	1.237	0.067		1.633	1.176	1.779	0.069	0.123	4.739	0.408
Abingdon	0.196	5.4	4.41	0.550	0.688		0.668	0.305	0.92	3.486	12.629	1.431
Merton Priory	0.495	4.248	3.186	0.134	0.287	0.114		0.129	0.463	1.17	15.831	0.334
St Mary Graces	0.419	3.767	2.688	0.102	0.24	0.089	0.000		0.864	1.424	16.408	0.816
Late Med. Combined	0.365	3.411	2.347	0.083	0.208	0.073	0.000	0.000		0.236	5.094	0.073
Chelsea Old Church	0.245	3.488	2.425	0.139	0.274	0.025	0.009	0.008	0.007		1.406	0.692
St Brides Crypt	6.075	0.059	0.552	3.867	2.621	5.63	4.564	4.136	3.810	3.893		12.616
St. Bride's Lower	0.957	P=0.336	P=0.556	0.124	0.025	0.563	0.299	0.273	0.252	0.310	P=0.305	

Table 5.42 Chi-squared (and fisher's exact probability, presented as p=) results for the comparison between all of the populations in this study: Results for the total population on the right are in grey and the comparison between the subpopulations without dental disease on the bottom left

5.2.5.5.1 Lesion type

In addition to the overall prevalence of sinusitis in the total sample and subsamples, the prevalence of the types of sinusitis defined by Boocock *et al* (1995) (see Section 4.2.3) were also recorded. The prevalence rates of these types are given in Table 5.43.

Remodelled spicules were the most common and white pitting by far the least common. There does not appear to be a correlation between the type of sinusitis and the presence of dental disease (see Figure 5.44). In order to determine whether these lesion types can be correlated with the cause, in this case dental disease, the prevalence of individuals with a particular lesion type and dental disease was recorded. One-hundred and forty-nine sinuses with spicules (52.1% of individuals with spicules) were also associated with dental disease. One hundred and fifty nine sinuses with remodelled spicules (44.3%) also had dental disease. Ninety-four sinuses with pitting also had dental disease, representing 47.5% of individuals with this lesion type. Ten of the 11 individuals (90.9%) with white pitting also had dental disease.

Site	Spicule Type	Remodelled Spicules	Pitting	White Pitting	Total
Iron Age	7	40	23	0	70
Lankhills	5	28	8	0	41
Roman London	11	24	6	0	41
Cannington	21	52	22	0	95
E. Med Combined	13	8	15	1	37
Abingdon	47	100	19	3	169
Merton Priory	21	29	42	0	92
Mary Graces	31	20	16	0	67
L. Med. Combined	21	7	4	0	32
Chelsea Old Church	33	2	11	1	47
St. Bride's Crypt	22	30	11	1	64
St. Bride's Lower	54	19	21	5	99
Total	286 (33.5%)	359 (42%)	198 (23.2%)	11 (1.3%)	854

Table 5.43: The frequency of each type of sinusitis in each of the samples examined in this study as a percentage of the total number of sinuses with sinusitis

Of the 854 sinuses with sinusitis recorded in this study, 438 had some connection to dental disease (49.16%). The sinuses with spicules were not more likely to be associated with dental disease than those without [$\chi^2(1)=0.363$, $p=0.547$]. The sinuses with remodelled spicules were not significantly more likely to be associated with dental disease than those without [$\chi^2(1)=1.836$, $p=0.175$]. The sinuses with pitting were not significantly more likely to be associated with dental disease [$\chi^2(1)=0.347$, $p=0.556$]. White pitting was the only type of sinusitis that was significantly more likely to be associated with dental disease than those without [$\chi^2(1)=7.577$, $p=0.006$], but this figure was derived from a sample of only eleven individuals. Assuming the white colouring in the case of white pitting is caused by woven bone, perhaps in future is would be more helpful to record whether a lesion is active or remodelled as well as osteoblastic or osteoclastic, rather than the types proposed by Boocock *et al* (1995)

	Sinusitis	**W/O Sinusitis**	**%**
Abscesses (D)	42	13	76.4
Abscesses (N)	70	75	48.3
AMTL	353	443	44.3
Sample W/O Abscesses (D)	812	2078	28.1
Sample W/O Abscess (N)	784	2016	28
Sample W/O AMTL	501	1648	23.3
Sample W/O any Dental Disease	389	1560	19.9

Table 5.44: The prevalence of sinusitis within subsamples of the total sample made up of only sinuses with abscesses both directly (D)as in the case of oro-antral fistulae and indirectly (N) affecting the maxillary sinus via a drainage sinus and antemortem tooth loss (AMTL). This is compared with the total sample not including those individuals to determine whether these forms of dental disease are significantly more likely to be found associated with sinusitis.

As is apparent in Table 5.44, the prevalence rates are higher in sinuses with dental disease compared to the sinuses without dental disease. The difference between the prevalence of sinusitis in individuals with abscesses directly in contact with the sinus is significantly higher than in the population without abscesses with drainage sinuses into the maxillary sinus [$\chi^2(1)= 28.093, p<0.001$]. Using odds ratios, the likelihood of an individual with an abscess directly in contact with the maxillary sinus having sinusitis is 2.06 times higher than an individual without dental disease, and 1.88 times higher than individuals without abscesses directly in contact with the maxillary sinus. The difference between the prevalence of sinusitis in the population with abscesses in the maxilla that do not come into direct contact with the maxillary sinus and the proportion of the population without abscesses in the maxilla is not statistically significant [$\chi^2(1)= 1.793, p=0.181$].

Site	Unilateral	Bilateral	Total
Iron Age	16 (37.2%)	27 (62.8%)	43
Lankhills	10 (38.5%)	16 (61.5%)	26
Roman London	15 (53.6%)	13 (46.4%)	28
Cannington	37 (56.1%)	29 (43.9%)	66
Combined Early Medieval Sample	15 (57.7%)	11 (42.3%)	26
Abingdon Vineyard	21 (22.1%)	74 (77.9%)	95
St. Mary Graces	25 (54.3%)	21 (45.6%)	46
Merton Priory	24 (41.4%)	34 (58.6%)	58
Combined Late Medieval Sample	8 (40%)	12 (60%)	20
Chelsea Old Church	19 (57.6%)	14 (42.4%)	33
St. Bride's Crypt	18 (43.9%)	23 (56.1%)	41
St. Bride's lower Crypt	29 (45.3%)	35 (54.7%)	64
Total	237 (43.4%)	309 (56.6%)	546

Table 5.45: Comparison of unilateral and bilateral cases of chronic maxillary sinusitis*- The number of individuals with unilateral and bilateral sinusitis*

The difference is significant if the prevalence in individuals with abscesses not in contact with the sinus are compared against the population that has no dental disease [$\chi^2(1)$= 5.661, p=0.017]. The difference in the prevalence of sinusitis in individuals with antemortem tooth loss in the maxilla and individuals without antemortem tooth loss in the maxilla is significant [$\chi^2(1)$= 7.124, p=0.008]. Using odds ratios, the likelihood of an individual with antemortem tooth loss having sinusitis is 1.22 higher than an individual without dental disease and 1.15 times more likely than individuals without antemortem tooth loss.

5.2.5.5.1.1 Unilateral vs. bilateral involvement

Table 5.45 gives the percentage of cases of sinusitis that were unilateral and bilateral. The percentage of unilateral cases is still 18.53% when dental disease is removed. There were three individuals with significant bone growth in one sinus, which could possibly be attributed to benign tumours. There was one individual at each of St. Bride's Crypt and St. Bride's Lower, and a third case found at Lankhills.

5.3 Prevalence of rib periostitis

As mentioned in the previous chapter, prevalence was only calculated per individual because, particularly in the earliest periods, it was often very difficult to identify the number of ribs (or their number in the rib cage) preserved from the small fragments available for observation. For each time period the prevalence for the sex and age groups are given as well as an overall prevalence for the population, which includes the individuals for whom age and/or sex were indeterminate. The sites within each period are compared to each other using chi-squared tests and fisher's exact tests. The prevalence of woven (active) and lamellar (healed) are given, as well as the general location on the rib, (head shaft or sternal end). The numbers of the ribs involved are also compared. This study examined 1053 individuals with ribs preserved. Of these individuals 172 (16.3%) had lesions on at least on rib.

5.3.1 Iron Age

Table 5.46 gives the prevalence of rib periostitis in the individual sites from the Iron Age that make up the combined Iron Age sample. Table 5.47 gives the prevalence of rib periostitis in the combined Iron Age sample and in each of the age and sex groups.

	N	n	%
Danebury	15	0	**0**
Suddern Farm	9	0	**0**
Yarnton	18	0	**0**
Mill Hill, Deal	16	1	**6.2**
Folly Lane	1	0	**0**
Micheldever Wood	2	0	**0**
Winnall Down	2	0	**0**
Total	63	1	**1.6**

Table 5.46: The prevalence of rib periostitis at the individual sites dated to the Iron Age. *The number of individuals with one or more ribs preserved (N) and the number of individuals with rib periostitis in one or more ribs (n)*

	N	n	%
Male	38	0	**0**
Female	17	1	**3.4**
Young Adult	28	1	**0**
Middle Adult	22	0	**0**
Old Adult	1	0	**0**
Total	57	1	**1.7**

Table 5.47: The prevalence of rib periostitis in the combined Iron Age sample- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

The individual sites that make up the Iron Age sample were not significantly different from each other. The prevalence of rib periostitis in males and females in the Iron Age sample was not statistically significantly different [p=0.372]. The differences between the age groups were also not significantly different from each other [p=1].

5.3.2 Roman Period

5.3.2.1 Lankhills

Table 5.48 gives the prevalence of rib periostitis in the total sample from Lankhills and within the individual age and sex groups from this site.

	N	n	%
Male	38	6	**14.3**
Female	23	2	**9.1**
Young Adult	13	0	**0**
Middle Adult	35	7	**17.7**
Old Adult	11	1	**10**
Total	61	8	**12.3**

Table 5.48: The prevalence of rib periostitis in the sample from Lankhills- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

The difference between the prevalence rates for males and females from Lankhills was not statistically significant [p=0.695]. There were no statistically significant differences between the three age groups at this site [Y-M p=0.311, Y-O p=0.467, M-O p=1].

5.3.2.2 Roman London

Table 5.49 gives the prevalence of rib periostitis in individuals who were excavated from sites within the Eastern and Western Roman cemeteries. Table 5.50 gives the prevalence of rib periostitis in the total sample from Roman London and within the individual age and sex groups from this site.

	N	n	%
Eastern Cemetery	65	14	**21.5**
Western Cemetery	16	0	**0**
Total	81	14	**17.3**

Table 5.49 The prevalence of rib periostitis in the individuals sites from Roman London that make up the combined sample from Roman London- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved.*

The difference between the individuals analysed from the Eastern and Western cemeteries was not statistically significant [p=0.061]. The difference between the males and females in the total sample from Roman London was not statistically significant [p=0.334]. The difference between the age groups in the sample were not statistically significant [Y-M p=0.745, Y-O p=0.581, M-O p=0.281].

	N	N	%
Male	58	9	**15.5**
Female	20	5	**25**
Young Adult	22	4	**18.2**
Middle Adult	51	8	**15.7**
Old Adult	6	2	**33.3**
Total	81	14	**17.3**

Table 5.50: The prevalence of rib periostitis in the combined sample from Roman London- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

5.3.2.3 Comparison

The difference between the two Roman sites was not significant [$\chi^2(1)=0.649$, $p=0.42$].

5.3.3 Early Medieval

5.3.3.1 Cannington

Table 5.51 gives the prevalence of rib periostitis in the total population and individual age and sex groups from Cannington.

	N	N	%
Male	55	2	**3.6**
Female	41	2	**4.9**
Young Adult	13	0	**0**
Middle Adult	79	4	**5.1**
Old Adult	3	0	**0**
Total	97	4	**4.1**

Table 5.51: The prevalence of rib periostitis in the sample from Cannington- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

The differences between the prevalence for males and females at Cannington was not statistically significant [p=1]. The differences between the three ages groups were also not statistically significant [Y-M p=1, M-O p=1].

5.3.3.2 Southeast combined sample (Edix Hill/Staunch Meadow)

Table 5.52 gives the prevalence of rib periostitis at the individual sites that make up the Southeast combined sample. Table 5.53 gives the prevalence of rib periostitis in the combined sample as well as the age and sex groups.

	N	n	%
Edix Hill	54	1	**1.8**
Staunch Meadow	18	1	**5.6**
Total	69	2	**2.9**

Table 5.52 The prevalence of rib periostitis in the two Early Medieval sites that make up the combined sample- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

	N	N	%
Male	39	1	**2.6**
Female	26	1	**3.8**
Young Adult	17	0	**0**
Middle Adult	47	2	**4.2**
Old Adult	2	0	**0**
Total	69	2	**2.9**

Table 5.53: The prevalence of rib periostitis in the combined Early Medieval South Eastern sample- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

The difference between the prevalence at Edix Hill and Staunch Meadow is not statistically significant [p=0.44]. The difference between the prevalence for males and females in the combined sample is not statistically significant [p=1]. The differences between the three age groups were not statistically significant [Y-M p=1, M-O p=1].

5.3.3.3 Comparison

The difference between the prevalence of rib periostitis at Cannington and in the combined Early Medieval sample when calculated with a fisher's exact test was not significant [p=1].

5.3.4 Late Medieval

5.3.4.1 Abingdon Vineyard

	N	n	%
Male	75	20	**22.2**
Female	44	12	**23.5**
Young Adult	39	8	**20.5**
Middle Adult	72	20	**27.8**
Old Adult	8	3	**37.5**
Total	122	33	**27**

Table 5.54: The prevalence of rib periostitis in the sample from Abingdon Vineyard- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

Table 5.54 gives the prevalence of rib periostitis in the sample from Abingdon Vineyard. The difference between the prevalence for males and females from Abingdon was not statistically significant [$\chi^2(1)=0.005$, p=,0.001]. The differences between the three age groups was not significant [Y-M $\chi^2(1)=0.708$, p= , Y-O p=0.367, M-O p=0.683].

5.3.4.2 Merton Priory

	N	n	%
Male	96	16	**16.2**
Female	6	0	**0**
Young Adult	9	0	**0**
Middle Adult	75	13	**17.3**
Old Adult	18	3	**16.7**
Total	102	16	**15.2**

Table 5.55: The prevalence of rib periostitis in the sample from Merton Priory- *The number of individuals with rib l periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

Table 5.55 gives the prevalence rates for rib periostitis at Merton Priory. The difference between the prevalence rates for the males and females from Merton Priory was not statistically significant [p=0.586]. The differences between the three age groups were also not statistically significant [Y-M p=0.343, Y-O p=0.529, M-O p=1].

St. Mary Graces

	N	n	%
Male	73	7	**9.6**
Female	19	1	**5.3**
Young Adult	28	2	**7.1**
Middle Adult	41	3	**7.3**
Old Adult	7	3	**42.9**
Total	76	8	**10.5**

Table 5.56: The prevalence of rib periostitis in the sample from St. Mary Graces- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

Table 5.56 gives the prevalence of rib periostitis in the sample from St. Mary Graces. The difference between the prevalence rates for males and females at St. Mary Graces was not statistically significant [p=1]. The difference between the young and old individuals [p=0.044] and the middle and old individuals [0.033] were statistically significant. The difference between the young and middle individuals were not statistically significant [p=1].

5.3.4.3 Urban, Low Status combined sample

	N	N	%
St. Nicholas Shambles	19	1	**5.3**
Guildhall Yard East	19	4	**21**
Total	38	5	**13.1**

Table 5.57: The prevalence of rib periostitis at the individual Late Medieval Sites. *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

	N	n	%
Male	25	3	**10.7**
Female	11	2	**18.2**
Young Adult	8	1	**12.5**
Middle Adult	28	4	**14.3**
Old Adult	2	0	**0**
Total	38	5	**13.1**

Table 5.58: The prevalence of rib periostitis in the combined low status Late Medieval Sample- The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved

Table 5.57 gives the prevalence of rib periostitis in the individual sites that make up the low status urban Late Medieval sample. The prevalence in the total combined sample is given in table 5.58. The difference between the populations from St. Nicholas Shambles and Guildhall Yard East was not statistically significant [p=0.34]. The difference between the prevalence rates for males and females was not statistically significant [p=0.631]. The differences between the three age groups were not statistically significant [All groups, p=1].

5.3.4.4 Comparison

Chi-squared results for the statistical difference between the four late medieval sites are given below in table 5.59. Differences that are statistically significant at 5% are given in red.

	Abingdon	Merton Priory	Mary Graces	L. Med. Combined
Abingdon		4.197	7.768	3.087
Merton Priory			0.994	0.139
Mary Graces				p=0.757
L. Med Combined				

Table 5.59: Chi-squared results determining the statistical significance of the difference between the prevalence rates for each of the populations from the Late Medieval Period. Statistically significant results are given in red.

5.3.5 Post Medieval

5.3.5.1 Chelsea Old Church

Table 5.60 gives the prevalence of rib periostitis at Chelsea Old Church. The difference between the prevalence rates for males and females at Chelsea Old Church was statistically significant [$\chi^2(1)=3.789$, p=0.04]. The differences between the three age groups were not statistically significant [Y-M p=0.329, Y-O p=0.427, M-O p=0.093].

	N	n	%
Male	48	18	**37.5**
Female	34	6	**17.6**
Young Adult	15	6	**40**
Middle Adult	53	11	**20.7**
Old Adult	15	7	**46.7**
Total	83	22	**29.7**

Table 5.60: The prevalence of rib periostitis in the sample from Chelsea Old Church- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

5.3.5.2 St. Bride's Lower (Low Status)

	N	N	%
Male	83	24	**28.9**
Female	38	12	**30**
Young Adult	14	2	**14.3**
Middle Adult	73	25	**34.2**
Old Adult	33	9	**27.3**
Total	121	36	**29.5**

Table 5.61: The prevalence of rib periostitis in the low status sample from St. Bride's Lower Crypt- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

Table 5.61 gives the prevalence of rib periostitis at St. Bride's Lower. The difference between the prevalence rates for males and females from St. Bride's Lower was not statistically significant [p=0.088]. The differences between the three age groups were not statistically significant [Y-M p=0.209, Y-O p=0.464, M-O p=0.507]

5.3.5.3 St. Bride's Crypt (High Status)

Table 5.62 gives the prevalence of rib periostitis at St. Bride's Crypt. The difference between the prevalence rates for males and females from St. Bride's Crypt was not statistically significant [p=0.282]. The differences between the young and middle age groups [0.041] and the middle and old age groups [p=0.006] were significantly different and the difference between the young and old age groups was not statistically significant [p=0.775].

	N	N	%
Male	68	13	**19.1**
Female	58	9	**15.5**
Young Adult	22	4	**18.2**
Middle Adult	25	0	**0**
Old Adult	78	18	**23.1**
Total	126	22	**17.5**

Table 5.62: The prevalence of rib periostitis in the high status sample from St. Bride's Crypt- *The number of individuals with rib periostitis in one or more ribs, as a percentage of the number of individuals with one or more ribs preserved*

5.3.5.4 Comparison

	Chelsea Old Church	St. Bride's Lower	St. Bride's Crypt
Chelsea Old Church		2.463	0.255
St. Bride's Lower			5.19
St. Bride's Crypt			

Table 5.63: Chi-Squared numbers showing the statistical significance of the difference between the prevalence rates for the Post Medieval samples. Significant results are shown in red

Table 5.63 gives the statistical difference between the prevalence rates at the three post medieval sites calculated using a chi-squared test. Significant results at 5% are given in red. Only the difference between the two samples from St. Bride's Church was significantly different. Neither was significantly different from the population from Chelsea Old Church.

5.3.6 Comparison of all Samples

There were no instances where an individual displayed rib lesions and the lesions pathognomonic of tuberculosis. As a result, no individuals were not included in the following section.

	Iron Age	Lankhills	Roman London	Cannington	Early Med. Combined	Abingdon Vineyard	Merton Priory	St. Mary Graces	Late Med. combined	Chelsea Old Church	St. Bride's Crypt	St. Bride's Lower
Iron Age												
Lankhills	f.026											
Roman London	9.212	.649										
Cannington	P=0.649	P=0.101	8.4									
Early Med. Combined	P=1	P=0.078	8.092	P=1								
Abingdon	17.955	4.883	2.609	20.227	17.175							
Merton Priory	8.377	.343	.084	7.353	7.146	4.197						
St Mary Graces	P=0.040	.1	1.486	2.706	.101	7.786	.994					
Late Med. Combined	P=0.027	P=1	.328	P=0.116	.094	3.087	.139	P=0.52				
Chelsea Old Church	16.757	4.164	2.035	18.132	15.792	.007	3.282	10.141	2.679			
St Brides Crypt	9.9	.79	.001	9.465	8.759	3.302	.128	3.662	.393	0.255		
St. Bride's Lower	20.457	6.456	4.050	23.603	19.804	.218	6.124	14.665	4.161	2.463	5.19	

Table 5.64: The chi-squared results to determine the statistical significance of the difference between the prevalence rates for rib periostitis in all of the samples examined in this study. Significant results are shown in red.

Table 5.64 shows the statistical significance of the differences between the prevalence rates of rib periostitis for all twelve samples. The true prevalence rates for rib periostitis are shown graphically for comparison in Figure 5.4.

In addition to recording the presence and absence of lesions, the location in the rib cage was also recorded. Figure 5.5 shows the frequency of lesions appearing on particular ribs.

Figure 5.6 shows the frequency of lesions that were active when the individual died (woven) and those which had begun healing (lamellar). Where an individual had both lamellar and woven lesions (7 individuals total) they were not included in the graph because they would increase the prevalence of both bars equally, as a result the total individuals represented in this graph is only 164.

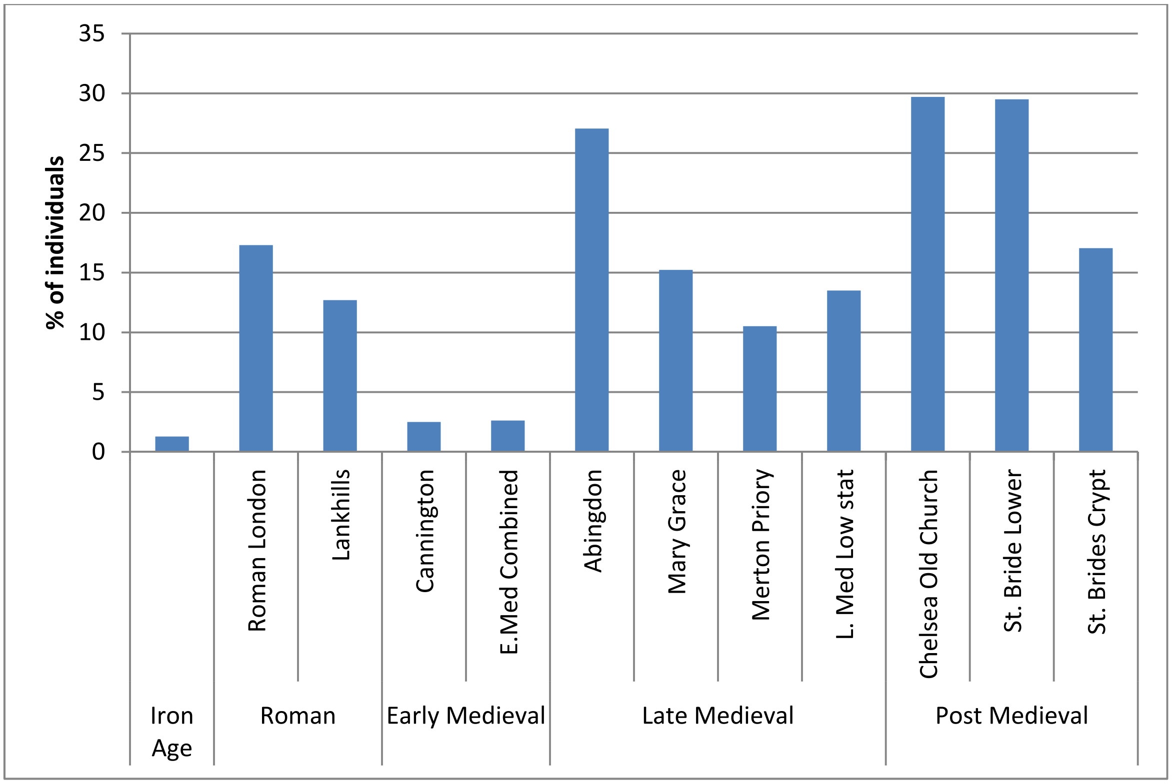


Figure 5.4: Prevalence of rib periostitis- *The number of individuals with at least one rib affected as a percentage of the number of individuals with ribs preserved for observation.*

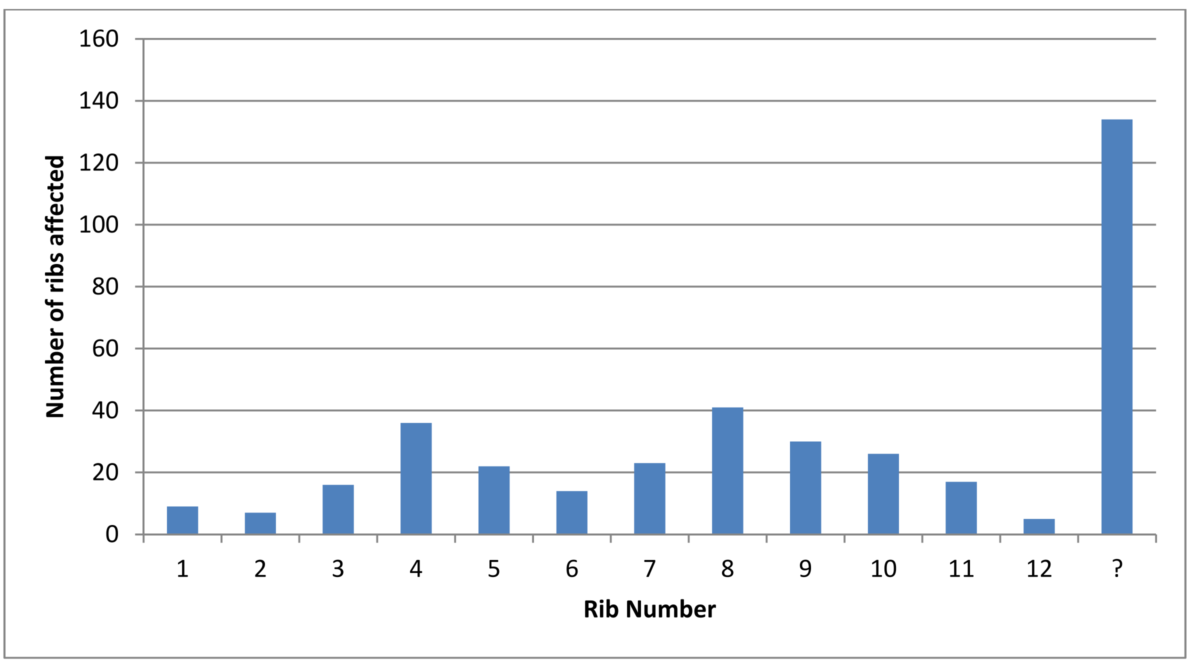


Figure 5.5: The number of times each rib was affected with rib periostitis of the total sample of 1053 individuals examined in this study from all samples,

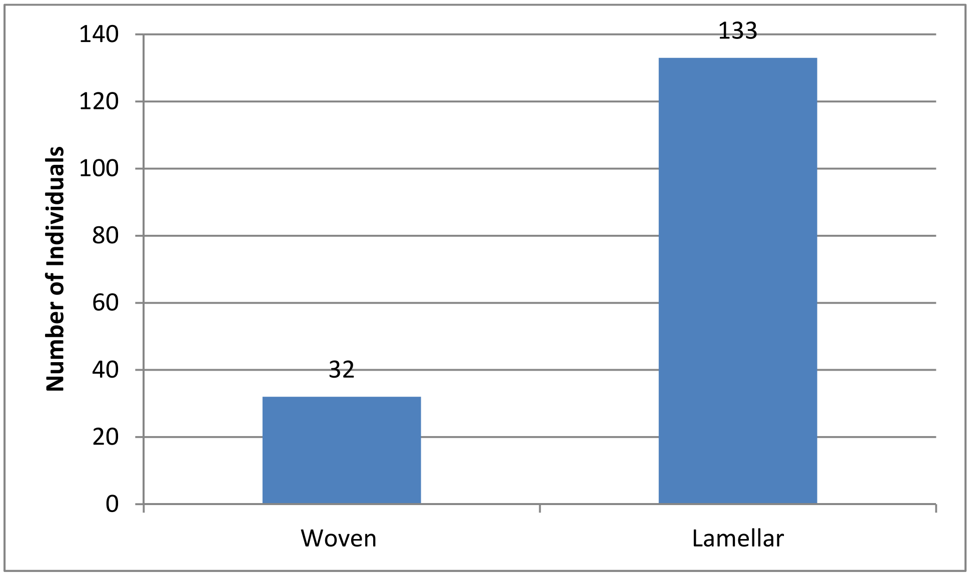


***Figure 5.6: Comparison of the prevalence of active versus inactive rib periostitis** - The number of individuals who had at least one rib presenting woven or lamellar bone.*

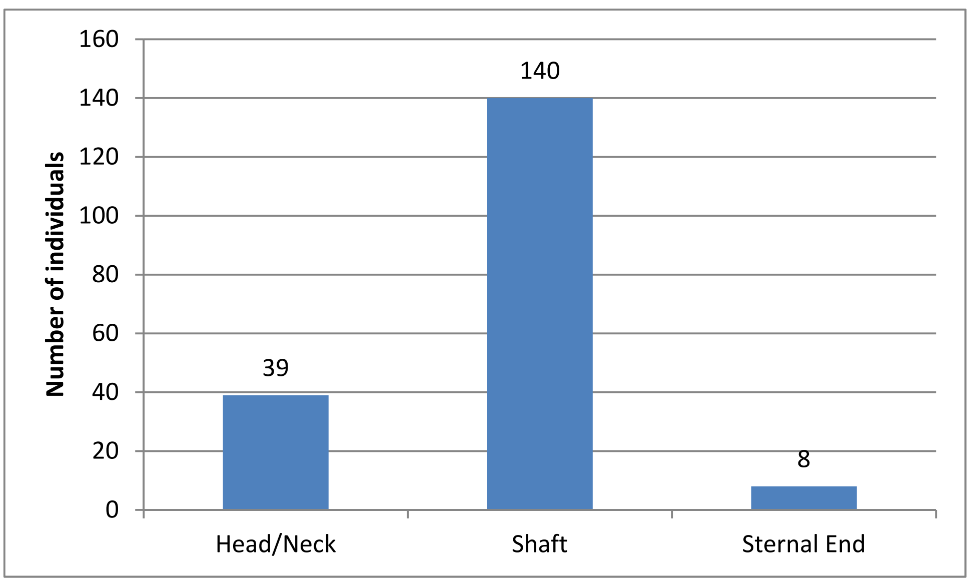


***Figure 5.7: The frequency of rib periostitis by location on the rib-** The number of individuals who had rib periostitis located on the head or neck, shaft or sternal end on at least one rib*

Figure 5.7 shows the frequency that lesions appeared on the defined areas of the ribs. There were no instances that a lesion spanned more than one of these defined areas. However, individuals with lesions with multiple lesions, in the rare case of those lesions not all being on the same part of the rib were not included in this graph. Figure 5.8 shows how frequently the lesions appeared on the left or right side of the torso. The lesions were slightly more frequently found on the shaft and on the left side of the body. However, this could be coincidence.

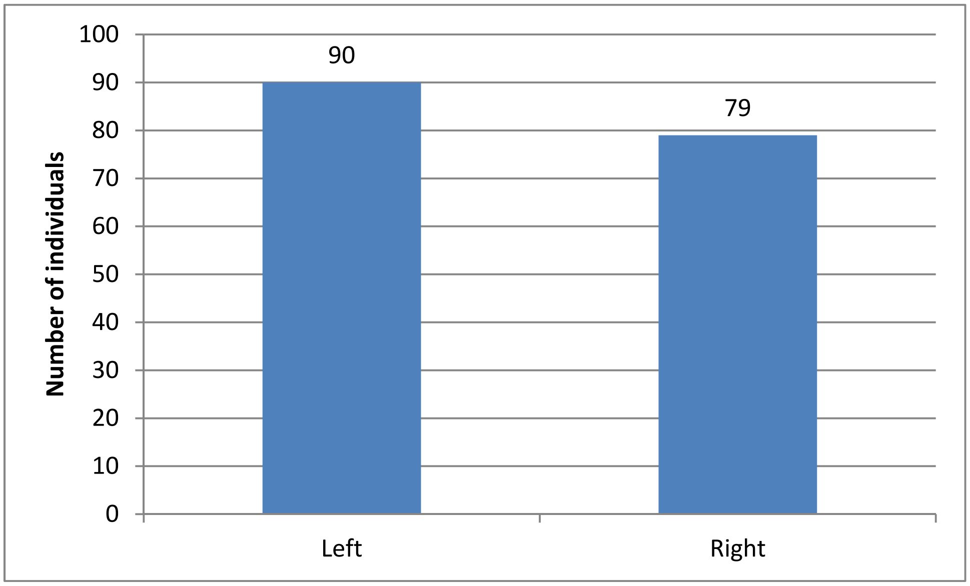


Figure 5.8: The frequency of lesions on ribs from the left and right side of the body. Individuals with lesions on both sides of the body are included in both categories, and individuals with unidentifiable rib fragments are not included.

5.4 Comparison by age

5.4.1 Chronic maxillary sinusitis

	Young Adult	Middle Adult	Old Adult
Sinusitis	128	314	95
Without Sinusitis	122	317	101

Table 5.65: The number of people with sinusitis in each of the age categories for the total sample of 1,078 aged individuals analysed with one or both sinuses preserved

The differences in chronic maxillary sinusitis frequency between the age groups for the total sample are given above in Table 5.65. The differences were only significant for young to middle adults at St. Mary Graces, and between the young and old adults age groups at Lankhills and St. Mary Graces. There were no significant differences between the middle and old adult age groups. Overall, for the 1,177 individuals from all of the samples for whom age could be estimated, the difference between the young and middle adult age groups was not significant

[χ^2(1)=0.003, p=0.953]. The difference was also not significant between the young and old adult age groups [χ^2(1)=0.002, p=0.969], or the middle and old adult age groups [χ^2(1)=0.01, p=0.922].

5.4.2 Rib periostitis

	Young Adult	Middle Adult	Old Adult
Rib Periostitis	28	97	46
Without Rib Periostitis	206	508	147

Table 5.66: Comparison of the number of individuals in each age group with rib periostitis (1041 total aged individuals with ribs preserved)

The differences between rib periostitis frequency in the age groups for the total sample are given in Table 5.66. The differences were only significant for young to middle adults at St. Bride's Crypt, for the young and old adult age groups at St. Mary Graces, and the middle and old adult St. Mary Graces and St. Bride's Crypt. Overall, for the 1,032 individuals from all of the samples for whom age could be estimated, the difference between the young and middle adult age groups was not significant [χ^2(1)=2.202, p=0.138]. The difference was significant between the young and old adult age groups [χ^2(1)=10.399, p=0.001], and the middle and old adult age groups [χ^2(1)=6.054, p=0.014].

5.5 Comparison by sex

5.5.1 Chronic maxillary sinusitis

	M	F
Sinusitis	36	179
Without Sinusitis	352	191

Table 5.67: The number of male and female individuals with sinusitis with one or both sinuses preserved.

The differences between the sexes for the total sample of 1,084 sexed individuals are given above in Table 5.67. The differences were only significant between the males/probable males, and females/probable females at St. Mary Graces. Overall, for the 1,203 individuals from the whole combined samples for whom sex could be estimated, the difference between males and females was not significant [χ^2(1)=1.527, p=0.217].

5.5.2 Rib periostitis

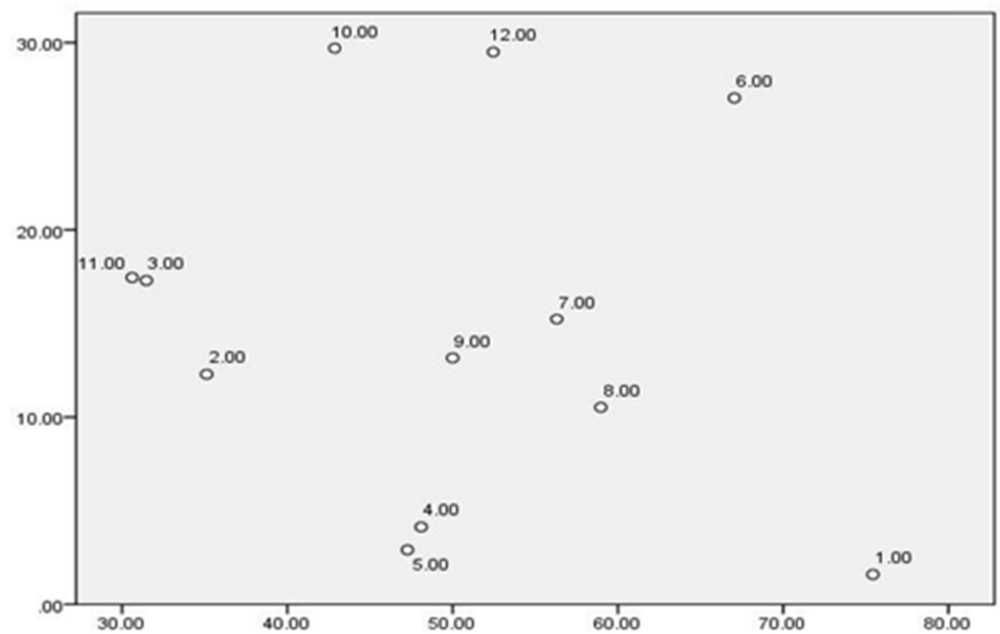
	M/M?	F/F?
Rib Periostitis	119	53
Without Rib Periostitis	576	288

Table 5.68: The number of males and females with rib periostitis in the total sample of 1,036 sexed individuals analysed who had ribs preserved

The difference between the sexes for the total sample is given above in Table 5.68. The difference was only significant at Chelsea Old Church. The overall difference between the males and females in the total sample of 1,036 individuals for whom sex could be estimated was not significant [$\chi^2(1)$=0.412, p=0.521].

5.6 Comparison between rib periostitis and sinusitis

ividuals
rib
ostitis



itis

Figure 5.9: Scatter plot: the percentage of individuals with sinusitis (x-axis) and rib periostitis (y-axis) of the total individuals with these elements available to analyse. (1= Iron Age, 2= Lankhills, 3= Roman London, 4= Cannington, 5= Combined E. Med. Sample, 6= Abingdon, 7= Merton Priory, 8= St. Mary Graces, 9= L. Med. Combined sample, 10= Chelsea Old Church, 11= St. Bride's Crypt, and 12= St. Bride's Lower.)

The prevalence of sinusitis and rib periostitis in these populations does not appear to be significantly correlated. Spearman's rho equals -0.119 p=0.713. There were 557 individuals with sinusitis in one or both sinuses and, of these, 91 had rib periostitis on one or more ribs. There are 571 individuals without sinusitis in either sinus and, of these, 78 have rib periostitis on one or more ribs. Using a chi-squared test, individuals with sinusitis were not more likely to have rib periostitis than those without sinusitis [$\chi^2(1)= 1.587$, $p=0.208$]. This is also clearly demonstrated in the scatter plot below (Figure 5.9). There is no positive or negative correlation pattern in the prevalence of sinusitis and rib periostitis for these twelve samples.

5.7 Summary

This chapter's main purpose has been to present the data collected in this study as thoroughly, objectively and transparently as possible so that it might be used by researchers in the future for comparison with other populations. Tables 5.69 and 5.70 below summarise the results for maxillary sinusitis and rib lesions. In the following chapters, these results will be discussed first in the context of other populations that have been examined previously, from both Britain and elsewhere, and secondly to determine the likelihood that any of the possible causes of respiratory disease is responsible for a significant proportion of the lesions visible in the sample.

	Male						Female						Indet. Sex	Total
Sample	Young	Middle	Old	**Total**	Indet.	**Total**	Young	Middle	Old	**Total**	Indet.	**Total**		
Iron Age	14/16	8/10	1/1	**23/27**	4/5	**27/32**	5/8	8/11	1/1	**14/20**	0/1	**14/21**	2/4	**43/57(75)**
Lankhills	1/7	10/30	4/6	**15/43**	0/2	**15/45**	1/7	7/15	3/4	**11/26**	0/2	**11/28**	0/1	**26/74(35)**
Roman London	7/18	11/40	3/5	**21/63**	0/0	**21/63**	1/7	5/15	1/1	**7/23**	0/0	**7/23**	0/2	**28/88(32)**
Cannington	5/11	32/58	5/5	**42/74**	0/3	**42/77**	4/9	19/43	1/2	**24/54**	0/0	**24/54**	0/0	**63/131(48)**
E. Med Combined	6/11	9/20	0/0	**15/31**	0/1	**15/32**	2/3	8/16	0/0	**10/19**	1/2	**11/21**	0/2	**26/55(47)**
Abingdon	16/28	40/51	1/5	**57/84**	2/6	**59/90**	12/16	16/28	4/5	**32/49**	1/2	**33/51**	0/1	**95/142(67)**
Merton Priory	4/8	37/70	12/18	**53/96**	0/3	**53/99**	2/3	3/4	0/0	**5/7**	0/0	**5/7**	0/0	**58/106(56)**
St. Mary Graces	13/20	20/31	4/5	**37/56**	0/0	**37/56**	4/14	3/6	2/2	**9/22**	0/0	**9/22**	0/0	**46/78(59)**
L. Med Combined	2/6	9/19	2/2	**13/27**	0/0	**13/27**	1/2	6/9	0/0	**7/11**	0/0	**7/11**	0/2	**20/40(50)**
Chelsea Old Church	2/6	12/27	5/14	**19/47**	0/0	**19/47**	7/9	5/17	2/4	**14/30**	0/0	**14/30**	0/1	**33/78(42)**
St. Bride's Crypt	4/12	2/13	16/45	**22/70**	0/0	**22/70**	4/10	5/15	10/39	**19/64**	0/0	**19/64**	0/0	**41/134(31)**
St. Bride's Lower	6/9	19/49	14/23	**39/81**	1/1	**40/82**	2/5	18/25	4/10	**24/40**	0/0	**24/40**	0/0	**64/122(52)**

Table 5.69: Summary of the prevalence rates for maxillary sinusitis in individuals from each sample, divided by age and sex. *Numbers to the left of the slash are the number of individuals with sinusitis. The numbers on the right of the slash are the total number of individuals with at least one sinus preserved. Numbers in parentheses are the percentage /prevalence rate.*

	Male						Female						Indet. Sex	Total
Sample	Young	Middle	Old	**Total**	Indet.	**Total**	Young	Middle	Old	**Total**	Indet.	**Total**		
Iron Age	0/21	0/12	0/1	**0/34**	0/4	**0/38**	1/7	0/10	0/0	**1/17**	0/0	**1/17**	0/2	**1/57(1.7)**
Lankhills	0/7	5/23	1/7	**6/37**	0/1	**6/38**	0/6	2/12	0/4	**2/22**	0/1	**2/23**	0/0	**8/61(12.3)**
Roman London	2/15	5/38	2/5	**9/58**	0/0	**9/58**	2/7	3/12	0/1	**5/20**	0/0	**5/20**	0/3	**14/81(17.3)**
Cannington	0/9	2/43	0/2	**2/54**	0/1	**2/55**	0/4	2/36	0/1	**2/41**	0/0	**2/41**	0/1	**4/97(4.1)**
E. Med Combined	0/13	1/24	0/1	**1/38**	0/1	**1/39**	0/3	1/21	0/1	**1/25**	0/1	**1/26**	0/4	**2/69(2.9)**
Abingdon	6/25	12/45	2/4	**20/74**	0/1	**20/75**	2/13	8/26	1/4	**11/43**	1/1	**12/44**	1/3	**33/122(27)**
Merton Priory	0/7	13/71	3/18	**16/96**	0/0	**16/96**	0/2	0/4	0/0	**0/6**	0/0	**0/6**	0/0	**16/102(15.2)**
St. Mary Graces	1/20	3/36	3/5	**7/57**	0/0	**7/57**	1/11	0/6	0/2	**1/19**	0/0	**1/19**	0/0	**8/76(10.5)**
L. Med Combined	0/5	3/18	0/2	**3/35**	0/0	**3/25**	1/2	1/9	0/0	**2/11**	0/0	**2/11**	0/2	**5/38(13.1)**
Chelsea Old Church	3/6	9/28	6/14	**18/48**	0/0	**18/48**	3/8	2/19	1/7	**6/34**	0/0	**6/34**	0/2	**22/83(29.7)**
St. Bride's Crypt	2/12	0/12	11/44	**13/68**	0/0	**13/68**	2/10	0/13	7/35	**9/58**	0/0	**9/58**	0/0	**22/126(17.5)**
St. Bride's Lower	1/9	17/50	6/23	**24/82**	0/1	**24/83**	1/5	8/23	3/10	**12/38**	0/0	**12/38**	0/0	**36/121(29.5)**

Table 5.70: A summary of the prevalence of rib periostitis in all the samples examined in this study. *Numbers to the left of the slash are the number of individuals with rib periostitis on at least on rib. Numbers to the right of the slash are the total number of individuals examined with ribs preserved.*

6 Discussion

6.1 Introduction

These results alone may begin to suggest a pattern in the prevalence of chronic maxillary sinusitis and rib periostitis through time in Southeastern England. However, when the results are put into context and compared with the results of other similar analyses we are able to gain a better understanding of the role of respiratory disease as well as requirements and difficulties of recording these lesions. This chapter will compare the results from previous analyses of chronic maxillary sinusitis and rib periostitis, discussed in Chapter Two, with the results from this study in order to elucidate any patterns that may suggest a predominant cause of either lesion. The meaning of the relative similarity or difference between these results will be discussed in the context of whether they support the hypothesis of this study or whether they can be better explained by alternative causes of these lesions. The results are then compared with samples analysed outside England from all time periods in order to determine whether there are any similarities or differences between populations with similar or very different environments, social status, or lifestyles. The final section will discuss the evidence that supports and contradicts the possible causes of respiratory disease that could potentially be verified by the archaeological record.

There have been only a few studies that have directly focused on these conditions. Most of the results given below were taken from site monographs or reports on human remains from particular sites, some of which have been published. Roberts and Cox (2003) did a comprehensive search of the published and grey literature, which covers all of the periods discussed here. The prevalence rates for both maxillary sinusitis and rib periostitis given in their book are also given below.

6.1.1 Crude prevalence rates versus true prevalence rates

As briefly discussed in Section 4.2.6.1, preferentially, the true prevalence rates (TPR) were used in this study. Unfortunately, this method of presenting data has only been used in a few previous analyses and the number of individuals with sinuses or ribs preserved are not always given so that a TPR can be calculated. Due to inconsistencies in reporting, in order to make the results comparable, Roberts and Cox (2003) presented all the prevalence rates for chronic maxillary sinusitis and rib periostitis as crude prevalence rates (CPR). These CPRs are also given below.

As discussed in previous chapters, there are innate problems with using CPRs because they are confounded by other factors such as preservation. CPRs usually take the number of individuals with a particular lesion or diagnosis and give this number as a proportion of the total number of individuals analysed, rather than as a proportion of the number of individuals who had the bone elements required to make the diagnosis preserved. In populations where the preservation of these elements is poor, there will be fewer individuals with that diagnosis because there are fewer individuals available to analyse for that condition. As a result, the crude prevalence will under-represent the real prevalence of the condition.

This difference will be clear in the following chapter when comparing the TPR and CPR for the sites that were examined in this study. In some cases where the difference between the TPRs is very small, the difference in the CPRs is significant, and vice versa. Unfortunately, as so few reports have presented TPRs for chronic maxillary sinusitis and rib periostitis, in order to place the results from this study in context, converting the results into CPRs was necessary. For each period, the sites for which TPRs have been calculated will be compared as TPRs, and frequencies for sites represented by CPRs are also compared.

In addition to the problem of recording methods, as these samples were examined under different conditions, the sample sizes range from less than ten to hundreds of individuals. Since such small samples are not statistically meaningful, sample sizes are given in cases where sample sizes were particularly low.

6.2 Respiratory disease in context

6.2.1 Respiratory disease in England

Including the twelve samples examined in this study there are 21 samples from England for which TPRs for chronic maxillary sinusitis have been calculated (see Figure 6.1). Given that these results are presented in the same way as the results of this study, they will be the most accurate and therefore the best comparisons.

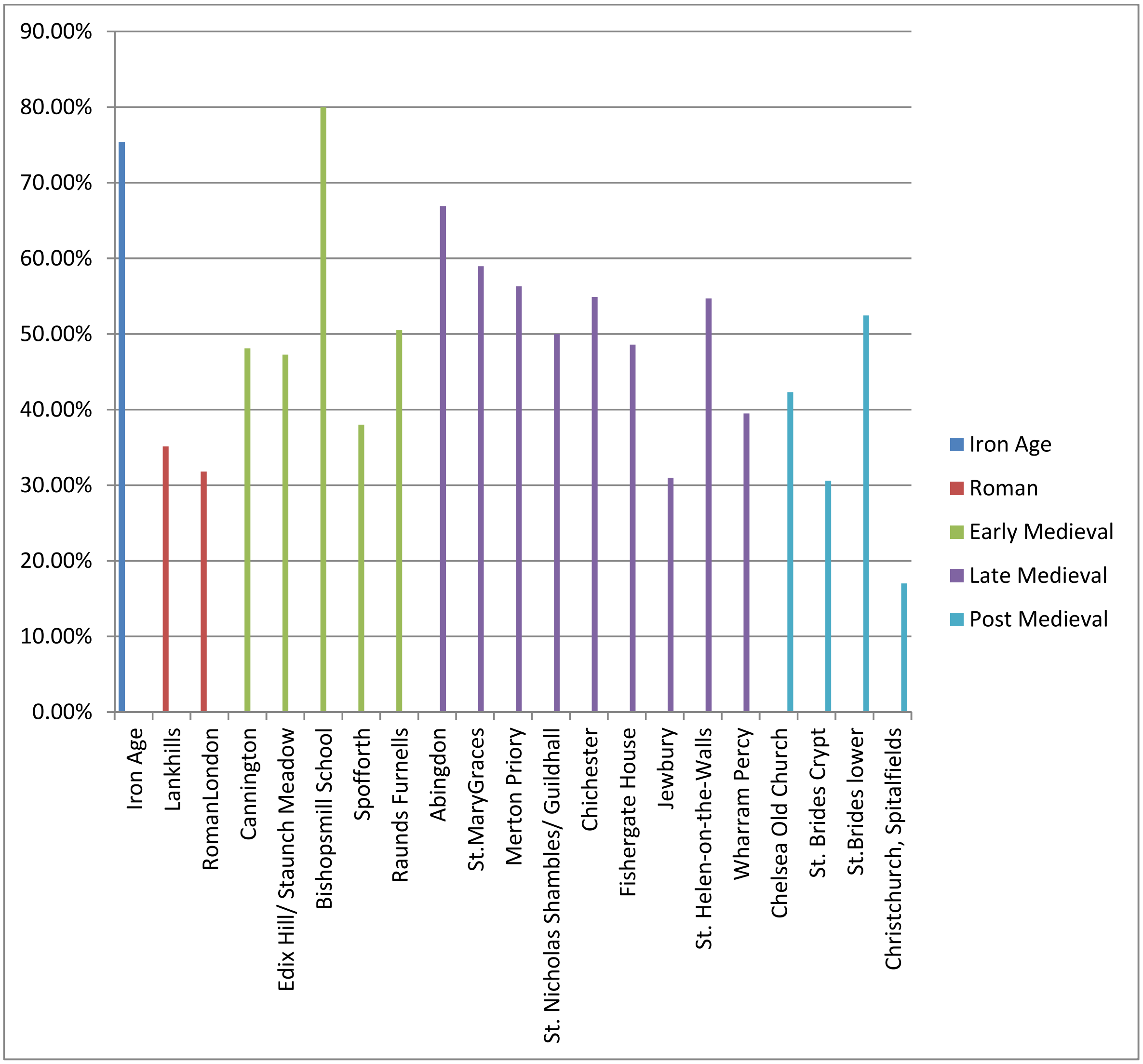


Figure 6.1: The true prevalence of chronic maxillary sinusitis in sites excavated in England for which TPRs were calculated. All samples, with the exception of Raunds Furnells, Chichester, Fishergate House, Jewbury, St. Helen-on-the-Walls, Wharram Percy, and Christchurch, Spitalfields, were recorded by this author.

6.2.2 Iron Age

The prevalence rates of chronic maxillary sinusitis in the seven populations examined from the Iron Age range between 63.6% and 100% or between 63.63% and 91.66% if the populations with less than five people are eliminated. The prevalence rate for the total sample is 75.4%, or 66.7%, when the number of sinuses affected rather than the numbers of individuals affected are used. This prevalence is markedly higher than in any of the other populations examined in this study. Unfortunately, there have not been any other Iron Age populations where TPRs have been recorded. Wells (1977) examined a selection of nine Iron Age skulls with complete sinuses and found that none of these individuals had chronic maxillary sinusitis. While this would be a true prevalence from the nine individuals, the skulls were chosen from a number of populations on the basis of being complete. How representative this would be of the populations they were sourced from is difficult to determine. Based on a search of the literature by Roberts and Cox (2003) one individual with chronic maxillary sinusitis was found at Beckford (Roberts 1987), which spanned the Iron Age and the early Roman Period, like Folly Lane, and another from Harrold, Bedfordshire (McKinley 1999). However, precisely what period during which these affected individuals were alive cannot be ascertained.

Even with a conservative estimate of the number of individuals who probably had sinuses preserved in the populations examined from this period, this would be significantly lower than the prevalence recorded here. This does not mean that the results in this study are anomalous. It is more likely that chronic maxillary sinusitis has not regularly been looked for in Iron Age populations, perhaps in part due to poor preservation. If this is the case, the lack of evidence for chronic maxillary sinusitis in these previous analyses does not necessarily signify a low rate of chronic maxillary sinusitis in the Iron Age population but rather a low rate of recording. Given the high rates of chronic maxillary sinusitis found in this study, this explanation seems plausible. However, it must also be taken into account, as mentioned in Section 4.1.1.6, that individual burial was not a common form of funerary rite in the Iron Age (Whimster 1981). This, combined with the age of these remains, mean that there are few Iron Age populations available for study and many of these do not have well preserved maxillae or ribs. This is why so many populations were combined for the Iron Age sample in this study, and could also explain the lack of research into these conditions in populations of this period.

The only rib lesion found in an Iron Age population in this study was from Mill Hill, Deal. It was composed of lamellar bone on the shaft of a lower left rib, possibly rib eight. The prevalence rate of 1.59%, is the lowest recorded in this study, a stark contrast to the prevalence rate for chronic maxillary sinusitis in the Iron Age, which was the highest prevalence rate recorded in this study. This low prevalence could result from the typically poor preservation of the remains from this period. It is possible that the more fragile woven bone lesions were lost post-mortem and that other inactive, lamellar lesions were lost when the cortex of the bone was damaged or where only small fragments or ribs were recovered.

According to Roberts and Cox (2003) there has been one individual with rib periostitis recorded from the Iron Age, as well as another two individuals from Beckford, which extended into the early Roman Period. Roberts (2000) recorded rib periostitis in one individual from Bourton-on-the-Water, Gloucestershire. Roberts and Buikstra (2003) also mention two (6.25%) individuals with rib periostitis from a sample of 32 individuals taken from Beckford, Hereford and Worcester. This is slightly higher than the result for this study, but not significantly.

With so few populations from this period having been examined for chronic maxillary sinusitis or rib periostitis, it is difficult to see any patterns in the prevalence rates. It is clear that the results for chronic maxillary sinusitis from the populations examined in this study are much higher than those previously recorded in other Iron Age populations. However, whether this is an accurate assessment or based on inter-observer error is impossible to say at this point. The very high prevalence of chronic maxillary sinusitis from the Iron Age populations that were examined in this study are most similar to, but higher than, the prevalence seen in the Abingdon Vineyard, a populations who were most likely mostly involved in agriculture, which could indicate that this environment is more likely to lead to sinusitis regardless of differences in housing and technology over time.

Furthermore, the prevalence of rib periostitis for the Iron Age was the lowest recorded in this study. According to the clinical literature smoke from biomass fuels, such as wood, lead to significantly higher rates of lower respiratory disease (World Health Organisation 2006). If there is no archaeological evidence of significantly poorer air quality, given the relatively good ventilation of their homes and lack of industrial activity this would explain the low prevalence rib periostitis, and by extension, chronic lower respiratory disease. However, this does not explain why the same populations suffer from such high rates of chronic maxillary sinusitis? It would appear that the markedly higher prevalence of chronic maxillary sinusitis in this population is caused by something other than air quality.

As discussed in Section 2.1.2, in addition to poor air quality, dental disease is a well-known contributor to chronic maxillary sinusitis (Brook 2006; Maresch *et al*. 1999; Mehra and Jeong 2009; Racic *et al*. 2004; Ugincius *et al*. 2006). Thirty-one of 57 individuals (54.4%) in this population suffered from severe dental disease in the form of abscesses or ante-mortem tooth loss. However, when these individuals are removed from the sample the prevalence is not significantly different to that recorded in the overall sample, and when the portion of the population with dental disease is compared against the portion of the population who did not have dental disease the difference remains non-significant. This is unexpected given the prevalence and severity of many of the dental lesions observed in these populations. The sinuses associated with antemortem tooth loss had a prevalence of chronic maxillary sinusitis of only 64% compared to the 100% where abscesses were directly associated with the maxillary sinus, and 91.67% in maxillary sinuses closely associated with abscesses that caused drainage sinuses elsewhere in the maxilla. In the half of the maxilla where there were none of these three scenarios, the prevalence of chronic maxillary sinusitis was only 50.67%, and much more comparable to the other samples examined in this study. Although on the higher end of the range, again, they were similar to the frequency in Late Medieval populations, who lived in a much different environment. Even this seemingly large difference between the prevalence amongst sinuses with abscesses and sinuses not associated with any dental disease was not significant when analysed with a chi-squared test (χ^2 (1)= 3.064, p=0.08). Does this mean that dental disease was not responsible for the high prevalence of chronic maxillary sinusitis at these sites? Given that the individuals with abscesses were nearly twice as likely to have bone lesions in their sinuses than those without, and these individuals made up slightly more than half of the population, this seems difficult to accept. It is likely that dental disease contributed much to the chronic maxillary sinusitis prevalence, although it would appear that other factors also contributed to the frequency, making the rate in those without dental disease not significantly different to those with dental disease.

The concentration of pollutants can have a significant effect on the prevalence of respiratory disease, but the types of pollutants are equally important. It is possible that certain sizes of particulates dominated during this period, which contributed more to upper or lower respiratory disease than in another period. For example, as discussed in Section 2.1.2, the nasal hairs typically filter out particles over 12µm, while particles 10µm may reach the lower respiratory system, although this depends on a number of factors including the shape of the particles and rate of breathing (Heyder *et al*. 1986; Jones 2001; Kim and Hu 1998; Lebowitz 1996). Larger atmospheric particulates, such as dust, pollen, or fungi may become trapped in the upper respiratory system leading to inflammation of the tissues in the maxillary sinuses, without being small enough to reach the lungs. However, smaller particulates and toxic gases such as those found in smoke, may reach, and ultimately cause inflammation in, the lower respiratory system. The lifestyle and environments of populations in this period were discussed in Sections 3.2.1, 3.3 and 3.4. Some information more specific to the lifestyles and environments of the Iron Age populations examined in this study are given in Section 4.1.2.1. Based on the archaeological investigation of the settlements associated with these human remains, there are no obvious activities that could be responsible for the very high prevalence of chronic maxillary sinusitis and the very low prevalence of rib periostitis. There is evidence of metalwork at most sites in this period, but these activities would not likely have been performed by most of the population, let alone frequently. Other activities including baking, pottery, and working stone or wood would have required less skill and been performed by more individuals (Cunliffe 2005). These activities could have exposed people to high concentrations of smoke in the case of the former two, and dust in the case of the latter. It is also possible that some of these activities were preformed less commonly in the following periods when many everyday items could be purchased, which could explain the lower prevalence in the following period. Agriculture would have been the occupation of most, if not all, of the population examined in this study. This would have exposed the population to high concentrations of dust, pollen, fungi, and animal dander during the course of their daily and annual activities. These particulates could be responsible for the high prevalence of chronic maxillary sinusitis seen in this period. As the buildings were relatively well ventilated, as a result of the materials used, it is possible that they suffered fewer lower respiratory conditions caused by exposure to smoke. This could explain the high rate of chronic maxillary sinusitis without a high prevalence of rib periostitis. However, agriculture would have been equally common in the later rural populations, and these populations did not have prevalence rates for chronic maxillary sinusitis that was this high.

However, also worth consideration are host factors. The Iron Age cemetery populations studied were small compared to the later populations. It has even been suggested in the case of Yarnton that the cemetery could have been composed of only a few families (Hey *et al*. 1999). If the small populations from the Iron Age were more likely to be related to each other than the members of any of the other populations examined in this study were to each other, the likelihood of rare genetic traits being more common is also higher. In this case, it is possible that factors such as facial physiology, allergies, or other genetic conditions that can cause chronic maxillary sinusitis lead to a disproportionate number of individuals with lesions. However, as with many other theories, such as the possibility that these individuals were buried as a result of illness or difference in lifestyle, this cannot be proved.

6.2.3 Roman Period

The two Roman samples examined in this study had the two lowest prevalence rates for chronic maxillary sinusitis of all the samples analysed, with the exception of the high status people from St. Bride's Crypt. This is in stark contrast to the Iron Age sample. The prevalence rates are also significantly lower than the samples from the Early Medieval Period, with the exception of the difference between the prevalence rates from Lankhills and the combined Early Medieval sample, which was nearly significant at five percent. There were no other Romano-British sites for which TPRs of chronic maxillary sinusitis have been calculated. When the results for Lankhills (26/284: 9.1%) and Roman London (28/891: 3.14%) are presented as CPRs, the results are more similar to those presented by Roberts and Cox (2003) (see Figure 6.2). Amongst their list of populations previously examined for chronic maxillary sinusitis, Roberts and Cox (2003) also give a CPR (0.9%) for the Eastern Roman Cemetery from London recorded by Conheeny (2000). This previous analysis recorded five individuals with chronic maxillary sinusitis in either one or both sinuses (Conheeny 2000). The current analysis of the Eastern Roman Cemetery recorded 21 (CPR= 3.8%) individuals with chronic maxillary sinusitis in one or both sinuses. This difference could represent differences in methodology used in both analyses. This study used an endoscope to analyse sinuses that were too complete to observe macroscopically, and this could account for at least some of the individuals affected that were not included in the previous analysis. It is also possible that inter observer error accounts for some differences.

The difference between the two populations analysed in this study is larger when calculated as crude prevalence rather than with true prevalence. Lankhills has the highest CPR for of all the populations from this period. The two sites from this study fall fairly well within the range of previously analysed sites. Lankhills has the highest rate for this period while Roman London is the fifth highest out of ten. The average for the previously analysed sites was 3.12%, very similar to the CPR for Roman London. However, since the CPR does not take account of the state of preservation of individuals at the site, it is difficult to say how accurate this comparison is.

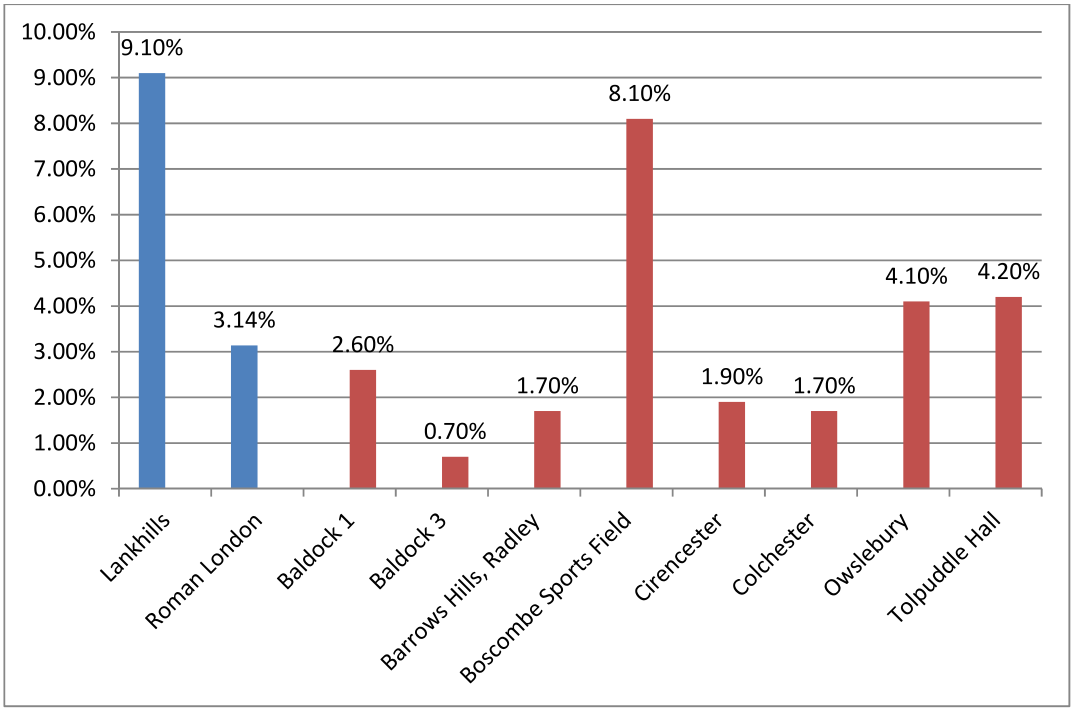


Figure 6.2: The CPR of chronic maxillary sinusitis in the previously recorded Romano-British samples compared to the results obtained in this study.

As mentioned in Chapter 2, there have been few Romano-British sites for which the prevalence of rib periostitis has been recorded. The CPRs, given in Roberts and Cox (2003), are shown in Figure 6.3. Of these sites, a total of 45 individuals with rib periostitis were reported. However, it is impossible to know how many individuals at these sites had ribs preserved. Of the total number of individuals recovered from all the sites included, the individuals with rib periostitis made up 2.1%, slightly higher than the rates here for Roman London or for Lankhills, when the prevalence rate is calculated in the same way (Roman London: 809 individuals excavated= 1.7%)(Lankhills: 284 individuals excavated= 2.5%).

The noticeably high CPRs recorded for Bancroft (Stirland 1994) was for a sample of only 8 individuals and may not be representative of a larger sample of the population. Aside from this, the CPRs range between 0.7% and 6.4%, with the average being 2.84%. With the exception of a few high prevalence rates, the two samples examined in this study are very similar to the previously examined samples.

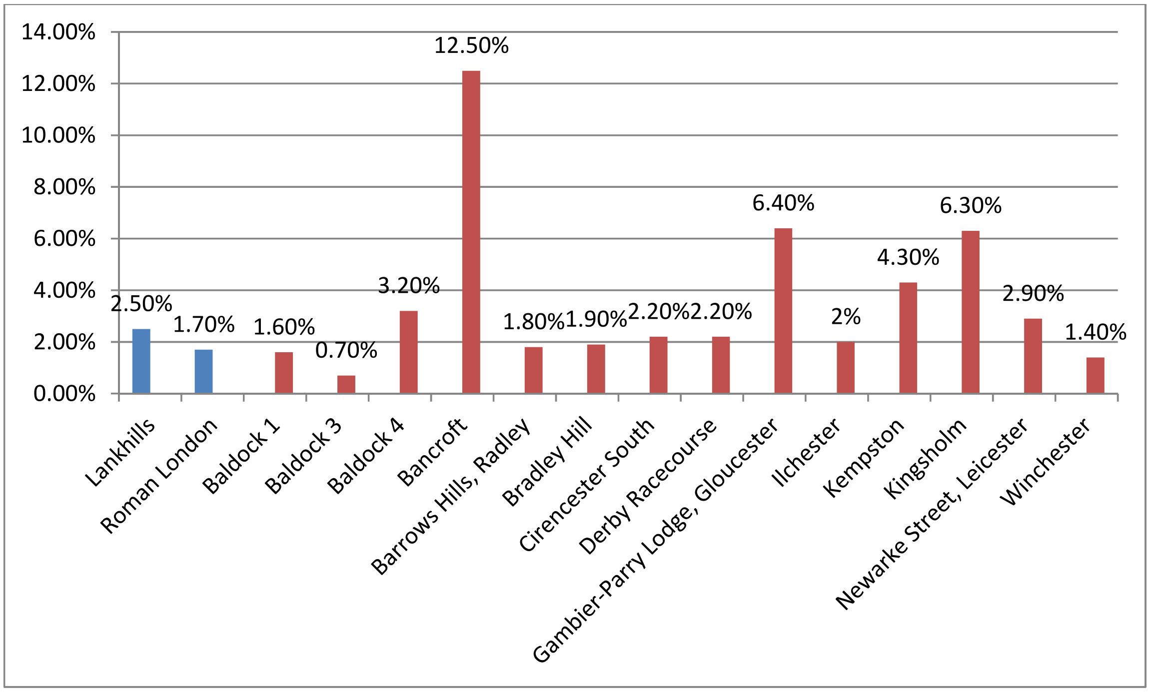


Figure 6.3: The CPR of rib periostitis for previously analysed Romano-British samples compared to the two samples examined in this study.

Again, Roberts and Cox (2003) give a CPR for rib periostitis in the Eastern Roman Cemetery taken from Conheeney (2000). Conheeney recorded seven individuals with rib periostitis. This study recorded 14 individuals with rib periostitis from the Eastern Roman Cemetery alone. It is not clear why this difference was observed. This could be accounted for by inter-observer error. Since the previous analysis was recording any pathological lesions in the skeleton, and this study was only looking for rib periostitis and chronic maxillary sinusitis, it is possible that this study recorded smaller, more subtle, less severe, lesions than were recorded previously.

There is a noticeable increase in the prevalence of rib periostitis between the Iron Age and the Roman Period in the sites discussed by Roberts and Cox (2003). This was also found to be the case in this study. The significantly higher prevalence in the Roman samples compared to the Iron Age samples could indicate a change in activities, climate, house type, fuel use, and several other environmental causes. It could also be attributed to increased pathogen exposure. The development of the Roman Empire would have significantly increased contact between Britain and the rest of Europe, as well as increased immigration, in particular, to the rapidly expanding population of London, which grew into a town wholly within this period (Alcock 2006; Barber and Bowsher 2000). It is this movement of people that would introduce new pathogens to British populations, and higher population density could better support transmission of communicable disease (Dobson and Carper 1996; McNeill 2003; Wilson 1996). If respiratory disease was more common due to these changes in population density and migration, this could also explain the increase in the prevalence of rib periostitis.

The prevalence rates for rib periostitis at Lankhills and Roman London were not significantly different. Lankhills and Roman London were towns, with few rural Romano-British cemeteries having been excavated. However, these towns would not have been urban in a modern sense, but it is expected that Roman London, which was a larger population centre, would have had higher prevalence rates if population density and infectious disease were affecting prevalence (Barber and Bowsher 2000; Clarke 1979). This is not the case as Lankhills had a higher prevalence, although not significantly so.

It is possible that this inverse relationship between the prevalence of chronic maxillary sinusitis and rib periostitis compared to the previous and following periods is a result of differences in lifestyle. If most of the individuals buried in these cemeteries spent little time involved with activities such as agriculture, it is possible that they could have been exposed to lower concentrations of particulates in the air and therefore suffered from less chronic maxillary sinusitis. However, the relatively high rates of rib periostitis would suggest that they inhaled something small enough to affect the lungs, without having any effect on the sinuses. Given that smoke contains particulates of various sizes, depending on the fuel, it seems unlikely that this would cause such high prevalence rates of rib periostitis without causing inflammation in the maxillary sinuses.

It is possible that the populations from this period were more likely to suffer from lower respiratory infections than the Iron Age or Early Medieval Period populations, who lived before and after them. If microbes were inhaled into the lungs, particularly if inhaled through the mouth rather than the nose, they might not have infected the maxillary sinuses, and therefore not lead to inflammation and bone lesions. Definite, macroscopically observed, cases of tuberculosis (TB) have been found in this region during this period (Roberts and Buikstra 2003) although there have also been cases recorded in the Iron Age (Mays and Taylor 2003). Since the pathognomonic indicators of TB are usually only seen in 3-5% of individuals, as they occur late in the disease process, there was probably a much higher prevalence of tuberculosis than is visible skeletally. Statistically, as the proportion of the population suffering from TB rises, the more likely an individual will present pathognomonic lesions. If, as has been suggested, rib periostitis can be early indicators of TB, which form earlier than the pathognomonic lesions (Matos and Santos 2006; Mays *et al.* 2002; Pfeiffer 1991; Roberts *et al.* 1998a; Santos and Roberts 2006), some of the individuals recorded as having rib periostitis in this study may have suffered from TB.

In addition to infectious disease in the lungs possibly accounting for some of the increase in the prevalence of rib periostitis, changes in the prevalence of dental disease could account for some of the decrease in the prevalence of chronic maxillary sinusitis. However, dental disease was recorded in 36 of 74 (48.6%) of individuals from Lankhills and 51 of 88 (57.9%) of individuals from Roman London. In spite of the higher amount of dental disease in Roman London, there was no significant difference in the prevalence of chronic maxillary sinusitis between these two populations, and within the populations, as with all other samples, there was no significant difference in the prevalence of chronic maxillary sinusitis in individuals with dental disease and those without.

6.2.4 Early Medieval Period

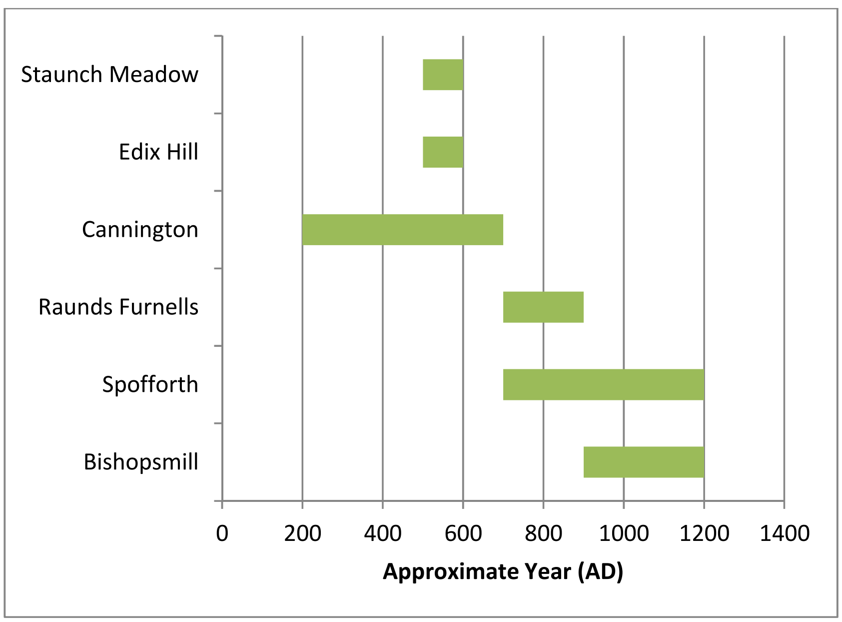


Figure 6.4: The dates that each of the Early Medieval cemeteries from which the skeletal populations derive are believed to be in use based on archaeological evidence and historical records.

Unlike in the previous two periods there were some populations that were previously examined specifically for chronic maxillary sinusitis from the Early Medieval Period. The dates for which these cemeteries were in use are given for comparison in Figure 6.4. As was the case with the whole population of Britain in the period, the populations lived in rural, or perhaps at most, small town settings (Blair 2003). There would not have been much difference between populations in terms of lifestyle and housing. There would be some difference in the climate between the southern populations examined here and ones that lived further north, such as Bishopsmill School and Spofforth (Bernofsky 2006). However, the slightly later date of these cemeteries could also account for any differences in the prevalence of chronic maxillary sinusitis or rib periostitis.

As can be seen in table 6.1, neither Cannington nor the combined sample of Edix Hill and Staunch Meadow were significantly different from either Spofforth or Raunds Furnells, which were in use later in the period and located in Yorkshire and Northamptonshire, respectively (see Figure 6.5).

	Bishopsmill School	Raunds Furnells	Spofforth
Cannington	χ^2=8.585, p=0.003	χ^2=0.133, p=0.715	χ^2=0.304, p=0.581
Edix Hill/Staunch Meadow	χ^2=7.533, p=0.006	χ^2=0.148, p=0.7	χ^2=0.168, p=0.682

Table 6.1: The statistical significance of differences between the two Early Medieval samples in this study and the three comparative sites. Chi-squared results that are significant at 5% are given in red

Bishopsmill School has the highest recorded chronic maxillary sinusitis frequency, not just among the sites from this period, but amongst all the results collected for England and elsewhere. It was statistically different from both of the Early Medieval Samples in this study. This may be due to the small sample size, as the sample from Bishopsmill School was made up of only 25 individuals with at least 10% of a maxillary sinus preserved from over one hundred individuals excavated at this site (Bernofsky 2006). This small sample may have had a randomly higher proportion of chronic maxillary sinusitis than the actual living population. Given that Spofforth was also significantly different to Bishopsmill School, its location in Northern England cannot account for this difference. Given that neither Spofforth nor Raunds Furnells were significantly different from the two samples recorded in this study, it is also unlikely that the later dates of the sites are responsible for Bishopsmill School's higher prevalence rate.

If Bishopsmill School is removed, the remainder of the population's lack of significant difference could be evidence that the similar lifestyles, housing, rural environment, and relatively similar climate, aside from the slight difference in latitude, are responsible for similar prevalence rates for chronic maxillary sinusitis. However, this could only be confirmed by comparing the populations to other populations for which these factors are significantly different and finding that they also had significantly different prevalence rates for chronic maxillary sinusitis. These populations will be compared with populations from other periods and populations from other countries later in this chapter.

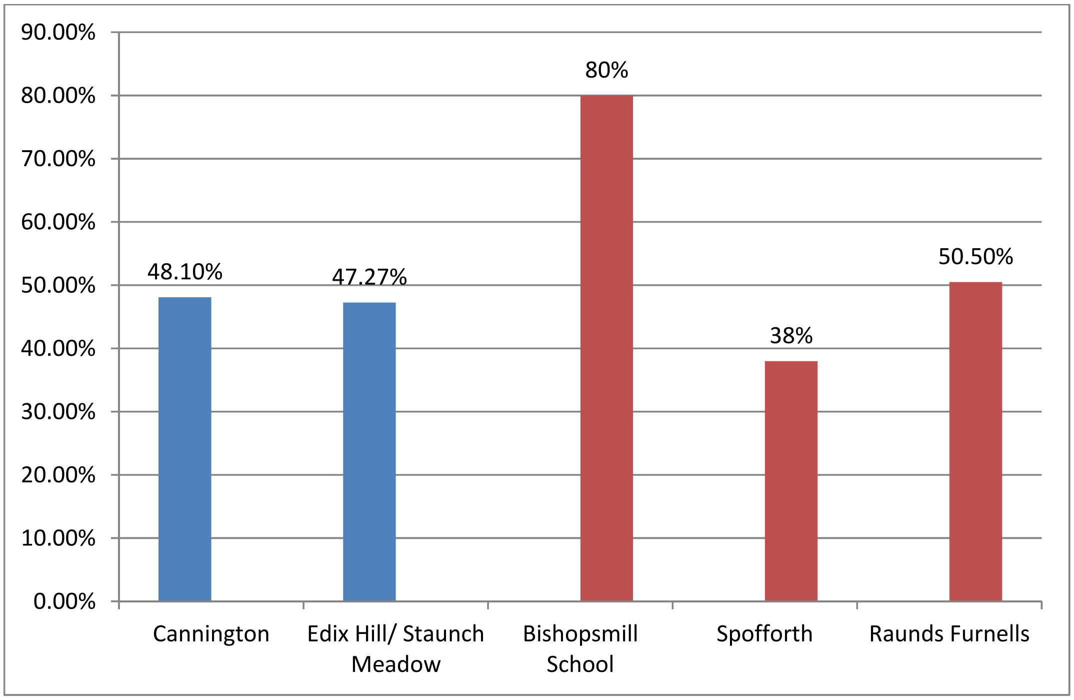


Figure 6.5: The TPR of chronic maxillary sinusitis calculated per individual in these (blue) and previously analysed populations (red) from the Early Medieval Period

However, these are not the only populations with chronic maxillary sinusitis recorded from this period. It is important to determine whether these similarities occur when including populations recorded with CPRs. Roberts and Cox (2003) give CPRs for 14 previously analysed Early Medieval sites. Thirteen of these are shown below in Figure 6.6, where they are compared with the three Early Medieval samples. Roberts and Cox (2003) also give a CPR for chronic maxillary sinusitis for Staunch Meadow reported by Anderson (1990) but this is not included in Figure 6.6. Anderson reported two individuals with chronic maxillary sinusitis at Staunch Meadow compared to the five individuals recorded here. This difference could be due to inter-observer error or preservation. The preservation of the human skeletal remains from this site was generally poor, and many of the maxillary sinuses were less than 25% complete. If these were not included in the original analysis due to poor preservation, this could account for the three fewer individuals. It is also possible that the less severe manifestations of these lesions were overlooked. The prevalence for Raunds Furnells (TPR given above) was converted by Roberts and Cox (2003) into CPRs in order to be comparable to the other sites given. Therefore, for comparison, this rate is also included in Figure 6.6.

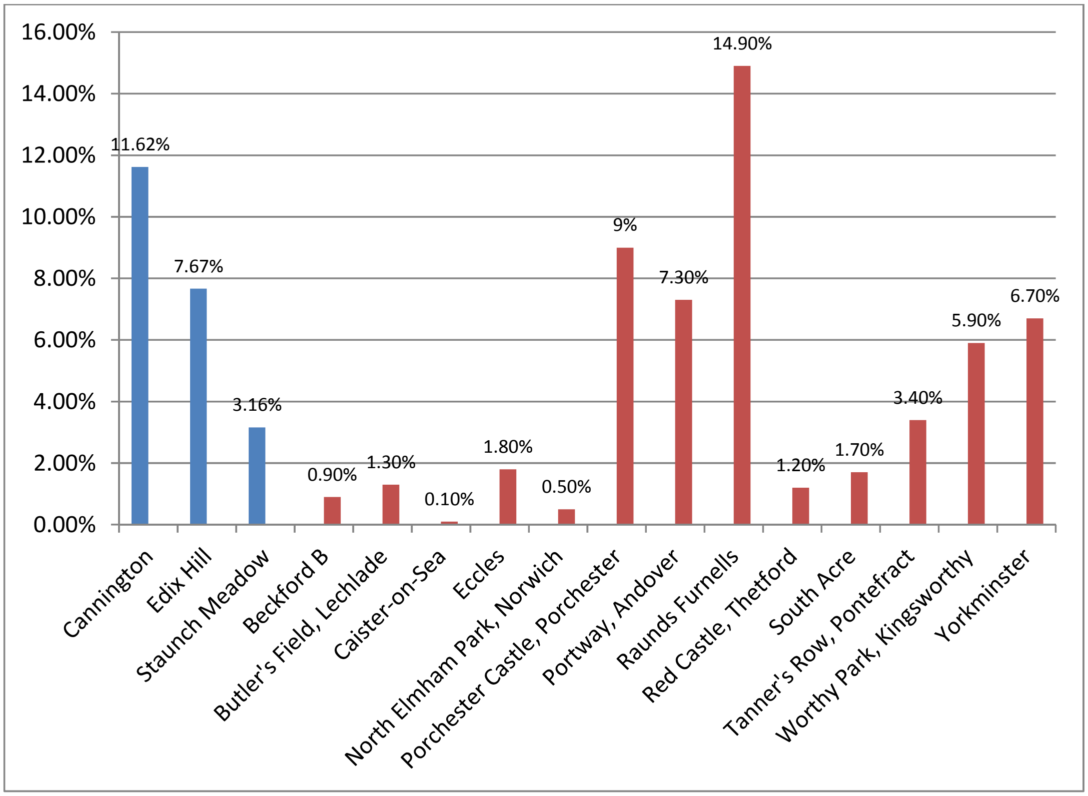


Figure 6.6: The crude prevalence of chronic maxillary sinusitis from previously analysed Early Medieval sites in Britain, compared to the three populations examined in this study.

The three populations used to make up the two samples in this study were amongst the five highest prevalence rates recorded for this period. As mentioned in Section 6.1.1, this could be due to preservation, as prevalence rates for populations with poor preservation of sinuses will appear lower when given as a proportion of the whole sample compared to when they are given as a proportion of those with sinuses preserved. This could also explain the relatively high rate at Raunds Furnells, which had a TPR only marginally higher than the TPRs calculated for the three early medieval populations in this study. However, information of preservation of particular bone elements is not always easy to determine from site reports. As the sinuses are positioned at the front of the body, when an individual is buried supine, the maxilla is one of the most shallowly buried bones, which means it is one of the bones most prone to damage. Even if an overall description of preservation for a population is described in a monograph as good or better, it is possible that the maxillae, or even ribs, may be more damaged than other more robust or more posterior bones (Henderson 1987; Waldron 1987).

Differences in the rates recorded for the three samples examined in this study to those recorded in site monographs could also be due to inter-observer error and differences in methodology. As the purpose of this study was to specifically look for these conditions, it is likely that smaller, subtle, less severe lesions would be more likely to be recorded here than in a general analysis of a population and, on occasions where the maxillae were more complete, the individuals were examined with an endoscope rather than not recorded.

Unfortunately, there were very few populations from this period that were examined for rib periostitis. Bishopsmill School had no rib periostitis in the twenty-five individuals examined and there was only one rib lesion found in the population from Spofforth (0.028%). According to Roberts and Buikstra (2003) there were 14 individuals with rib periostitis, which was an increase from the Roman Period. Their CPRs are given in Figure 6.7.

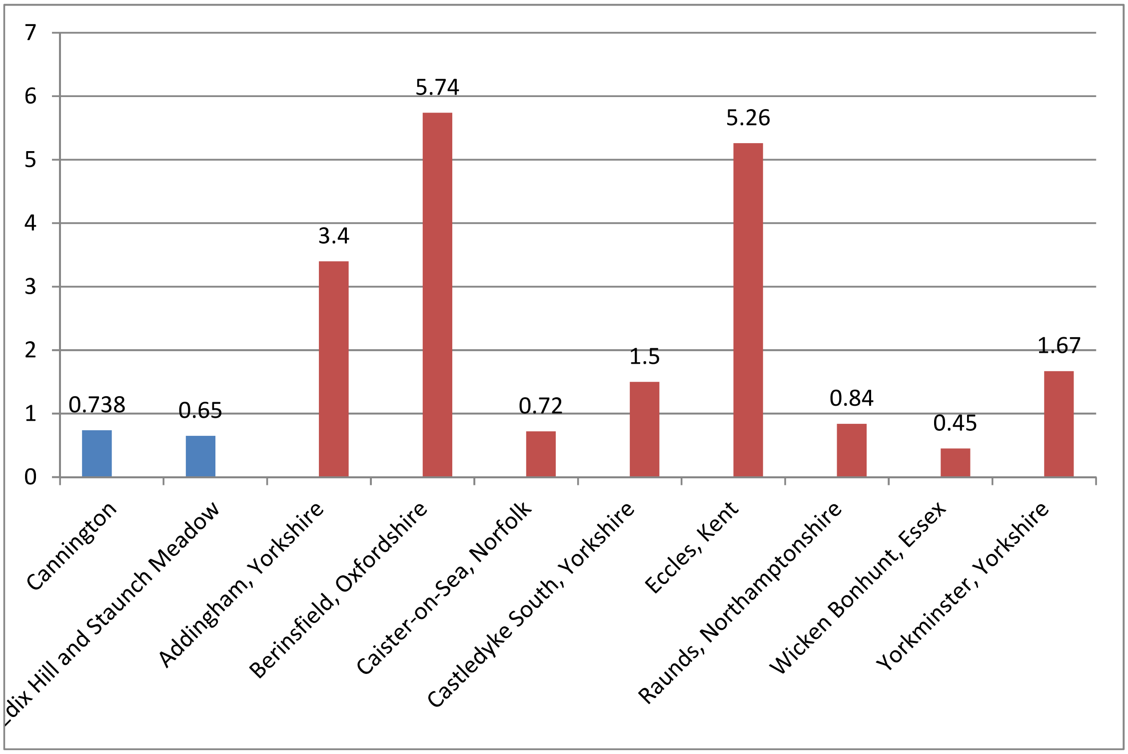


Figure 6.7 : The crude prevlaence per individual of rib periostitis in the samples recorded in this study (blue) and recorded previously (red)

Unlike in many of the periods, the two populations examined for this study have among the lowest CPRs. However, there is less than five percent difference between the highest and lowest CPRs for all the populations shown above.

During the Early Medieval Period, England reverted to a primarily rural environment (Blair 2003). This could account for the difference between this period and the two urban populations from the Roman Period. While not as high, results for this period more closely mirror the Iron Age than the relatively urban Roman Period, with its comparatively high rate of chronic maxillary sinusitis and low rate of rib periostitis. Again, the exposure to larger particulates that could have caused inflammation in the maxillary sinuses but not reached the lungs could result in this difference, but there is no reason to expect that this population would be exposed to lower concentrations of these particulates than the Iron Age populations who had much higher prevalence rates from chronic maxillary sinusitis. This does not explain why the results were so much lower for these two samples than for the Iron Age.

It is possible that dental disease is responsible for some of the decrease in the prevalence of chronic maxillary sinusitis from the Iron Age. Individuals with dental disease accounted for 54.4% of the Iron Age sample while they accounted for only 32.1% (Cannington) and 29.1% (Southeast Combined sample) in the two Early Medieval Samples. As with the previous periods, there was no significant difference between the subsamples with and without dental disease, which suggests that dental disease was not a significant contributor. However, while the differences between the prevalence rates for chronic maxillary sinusitis in the total samples are significant, the difference between the populations when individuals with dental disease are removed cease to be significant, suggesting that the similarity in lifestyle could be responsible for similar prevalence rates for sinusitis when dental disease is not a factor.

6.2.5 Late Medieval Period

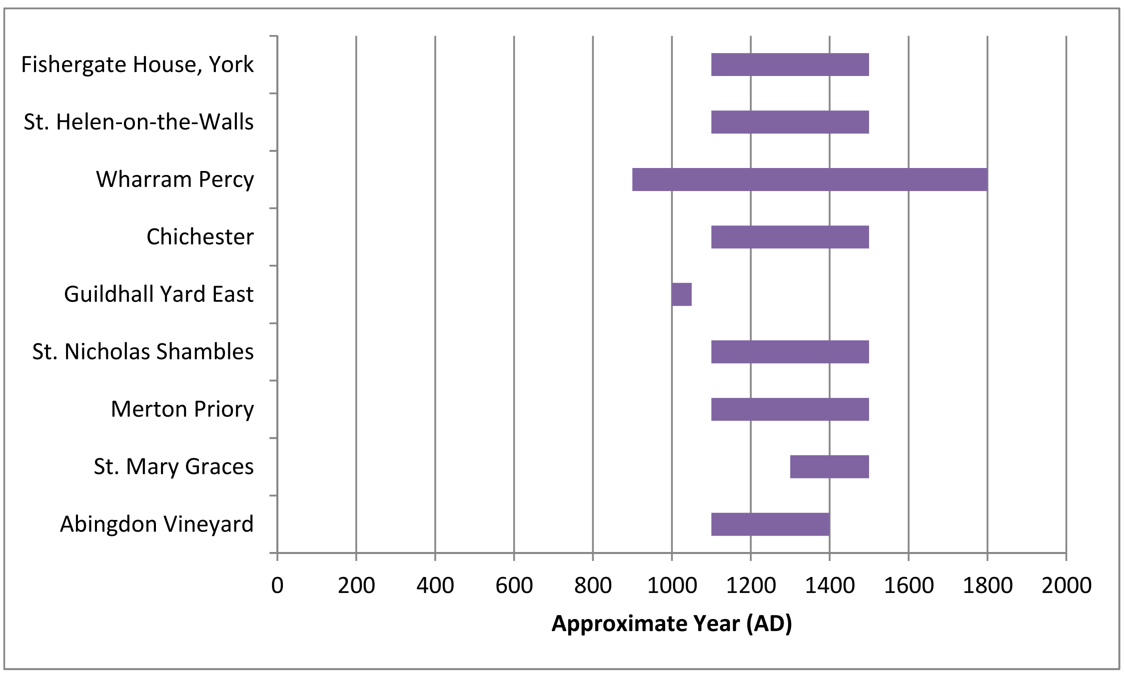


Figure 6.8: The years of the use of the cemeteries for the samples based on archaeological and historical records

Based on the results of previous research and the samples recorded in this study (see Figure 6.8), the prevalence of chronic maxillary sinusitis in the Late Medieval Period appears to be relatively similar regardless of location in the country and social status (see Figure 6.9). Table 6.2 gives the chi-squared results for the comparison of the four samples in this study to the four previously analysed populations. Abingdon and Wharram Percy were the only populations that were significantly different to any of the other comparative sites (Chichester, St. Helen-on-the-Walls, and Fishergate House, York). These two populations make up the upper and lower range of for this period. When the individuals below the age of 17 are removed from Wharram Percy the prevalence is much more similar (51.4%) to the rest of the populations, however, when the same is done for St. Helen-on-the-Walls, the prevalence increases to 63.3% (See Section 2.2.2.1.4)

	Chichester	Fishergate House	St. Helen-on-the Walls	Wharram Percy
Abingdon	χ^2=4.09, p=0.043	χ^2=8.514, p=0.004	χ^2=5.052, p=0.0246	χ^2=8.134, p=0.004
Merton Priory	χ^2=0.042, p=0.837	χ^2=1.254, p=0.263	χ^2=0.025, p=0.8738	χ^2=7.806, p=0.0052
St. Mary Graces	χ^2=0.32, p=0.32	χ^2=1.955, p=0.162	χ^2=0.238, p=0.5947	χ^2=8.481, p=0.0036
L. Medieval Combined	χ^2=0.304, p=0.582	χ^2=0.022, p=0.882	χ^2=0.145, p=0.7031	χ^2=1.169, p=0.2796

Table 6.2: The results of chi-squared tests comparing each of the Late Medieval sites to the comparative sites previously analysed. Results that are significant at 5% are in red.

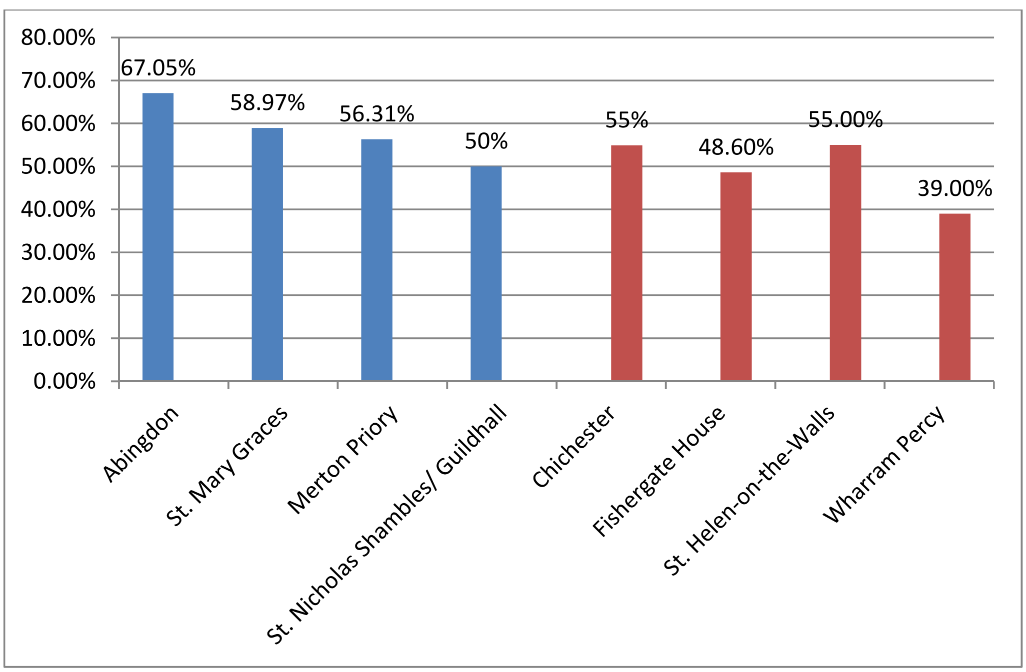


Figure 6.9: TPR of individuals affected by chronic maxillary sinusitis calculated in the populations from this study (blue) and previously recorded Late Medieval samples from England (red).

Roberts and Cox (2003) give CPRs for nine sites, including Chichester, St. Helen-on-the-Walls, and Wharram Percy, for which TPRs are given above. These sites are shown below in Figure 6.10. Of these, the studies of Chichester, Jewbury, Kirk Hill, St. Helen-on-the-Walls, and Wharram Percy specifically refer to chronic maxillary sinusitis, while the remaining five sites record rates for sinusitis in general. Whether any sinusitis occurred in sinuses other than the maxillary sinuses is unknown. However, the other facial sinuses are smaller and less likely to be broken post-mortem, making it less likely that sinusitis will be visible unless they are accessed specifically using a drill.

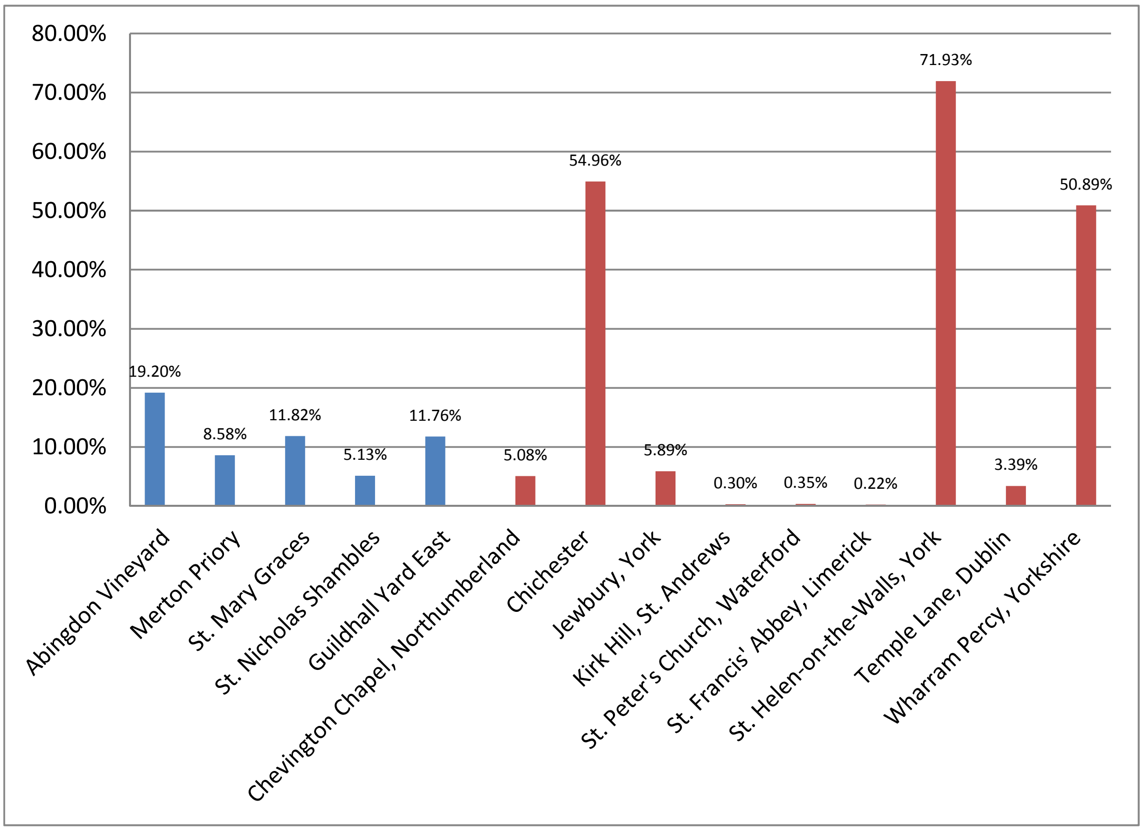


Figure 6.10: The CPR of chronic maxillary sinusitis from Late Medieval populations in Britain and Ireland compared to the five populations examined in this study.

The prevalence rates from St. Helen-on-the-Walls, Chichester, and Wharram Percy are all noticeably much higher than any other population shown in Figure 6.10. However, given that the TPRs for these populations were not significantly different from the Late Medieval populations examined in this study, it is clear that their apparent differences in Figure 6.10 are a result of the method of calculation (CPR) rather than an actual difference in prevalence.

Unfortunately, like in the other periods in this study, there were no studies that have specifically recorded rib periostitis. Rib periostitis may have been recorded during the general analysis of a population or as a possible indicator of specific respiratory disease, such as tuberculosis. Roberts and Buikstra (2003) found 138 individuals with rib periostitis recorded in the literature. The CPRs of these sites are given below in Figure 6.11.

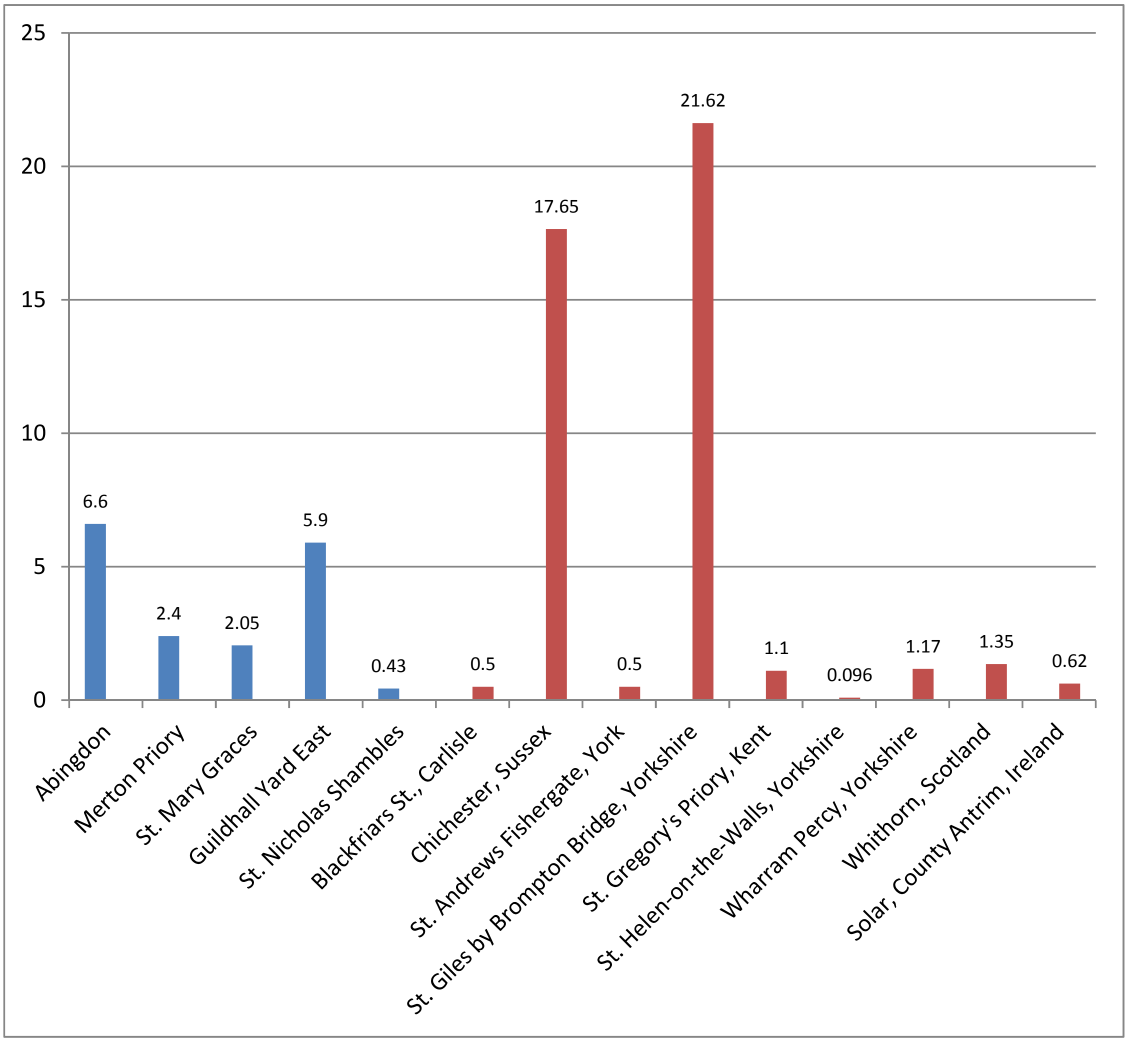


Figure 6.11: The CPR of rib periostitis in the Late Medieval Period in Britain and Ireland (red) compared to the crude prevalence rate results obtained in this study (blue)

It would be expected that the rates in this period would be higher than the previous periods, as it was during this time that urban environments became more population dense (Lilley 2002). In spite of the high population density, houses were still primarily made of materials that allowed more ventilation, such as wattle, daub, and thatch. Wood was still the primary choice of fuel, and chimneys were very uncommon

(Brimblecombe 1987; Letts 2000). However, houses were built to allow for a desired level of smoke, which would help limit certain types of vermin and bacteria in the home, but also allow the occupants to breathe comfortably (Letts 2000). This was done by keeping activities close to the floor where the concentrations of smoke were the lowest, and including in their structures, openings for smoke to escape either through windows or in the roof (Letts 2000).

The movement of people into larger population centres also resulted in a change in the methods of subsistence from farming to increased specialisation for the urban population (Dyer 2000). These occupations required individuals to perform a smaller range of tasks more frequently to provide goods and services to other individuals who no longer performed these task themselves (Dyer 2000). This is different from the form of subsistence farming that would have occurred in previous periods. Individuals who chose specialisations that frequently exposed them to poor air quality, such as baking, pottery, or metalwork, would be exposed to smoke for much longer periods of time than individuals who performed these activities less frequently. Even those in rural environments in the Late Medieval Period who continued farming would be required to produce excess to support the growing urban populations (Dyer 2000). This more intensive farming could expose the individuals involved to higher concentrations of particulates in the air if it resulted in increased concentrations of pollen and dust (Kirkhorn and Garry 2000). However, even in the urban environment some agricultural activities still occurred, such as the rearing of animals (Keene 1983). Particulates, such as animal dander, would have added to the other domestic particulates, such as dust and smoke, particularly in small urban spaces inhabited by lower social status individuals, which could potentially lead to higher rates of chronic maxillary sinusitis and rib periostitis.

The two urban samples from this period examined in this study lived in roughly the same area of London (see Figure 4.6). The low status populations most likely worked in some form of trade and were most likely exposed to higher concentrations of air pollution on average than their higher status urban counterparts. The excavation of an area with multiple ovens suggested that some individuals baked and provided food for the local workers (Bowsher *et al*. 2007). Whether any, or any significant number, of the individuals excavated from the parish cemetery were bakers by trade cannot be known, but this is a possible occupation that could have exposed them to high concentrations of smoke on a daily basis. However, there was no significant difference between these two urban populations.

In contrast, the high status rural population from Merton Priory likely spent relatively more time indoors than the other Late Medieval samples, although they may have participated in some gardening (Miller and Saxby 2007). They may have been exposed to higher amounts of smoke from fires and candles used for light or heat. They may also have been exposed to smoke from incense. In this case, the expectation would be a result similar to the Roman populations who, as was theorised in Section 6.2.3, were urban and therefore exposed to relatively lower concentrations of particulates than the rural populations that preceded and preceded them. The prevalence rates for chronic maxillary sinusitis were not significantly lower than the urban populations. It is possible that even as late as the Late Medieval Period the concentration of particles in the air in London was lower than those in the rural environment. This could explain the relatively high prevalence in the only rural population, Abingdon Vineyard. The high prevalence of chronic maxillary sinusitis in this population could be caused by inhaling dust, pollen, fungi, and other particulates created by agricultural activities. This is further confirmed by the lack of significant difference between these urban populations in the Late Medieval Period and the two urban populations from the Roman Period. The Roman populations were only significantly different from the more rural Abingdon, with the exception of the relatively rural Lankhills being significantly different from Merton Priory (see Table 5.42). However, the statistical significance between Abingdon and the other three Late Medieval samples disappears when the individuals with dental disease are removed from the samples from this period, which makes this theory less tenable.

As with the previous periods, it is likely that, to some extent, dental disease contributed to the prevalence of chronic maxillary sinusitis. However, when the individuals with dental disease are removed from the sample, the prevalence of rib periostitis still does not correlate with chronic maxillary sinusitis. There was also no significant difference in the prevalence of chronic maxillary sinusitis amongst the proportion of the population with dental disease and those without, as with the other periods. Furthermore, even where dental disease and sinusitis are found together, the sinusitis may have predated the dental disease. Given the lack of relationship between dental disease and the prevalence of chronic maxillary sinusitis, not just in this period but in all the periods previously discussed, it seems unlikely that dental disease is a primary cause of this condition, but rather just a contributor.

There is a significant increase in the prevalence of rib periostitis between the Early Medieval Period, where the prevalence is extremely low, and the Late Medieval Period. If we attribute these lesions to infection, it is possible that living in urban environments where population densities were higher, and therefore the risk of becoming infected with communicable diseases was higher, that this change in lifestyle could account for the higher rates of rib periostitis. However, it is also possible that changes in lifestyle and diet could affect health in general. The individuals with healthier diets and lifestyle may have had stronger immune systems. This would have allowed them to fight off infections longer before succumbing. However, there is no reason to assume that individuals in these populations were healthier, or had stronger immune systems, than individuals during any of previous periods. Therefore, this is an unsatisfactory explanation in this case.

Unfortunately, since many of the factors that affect exposure to disease are also linked to the factors that expose people to poor air quality, such as high population density, it is difficult to determine which of these two factors actually resulted in the lesions visible on the ribs.

6.2.6 Post Medieval Period

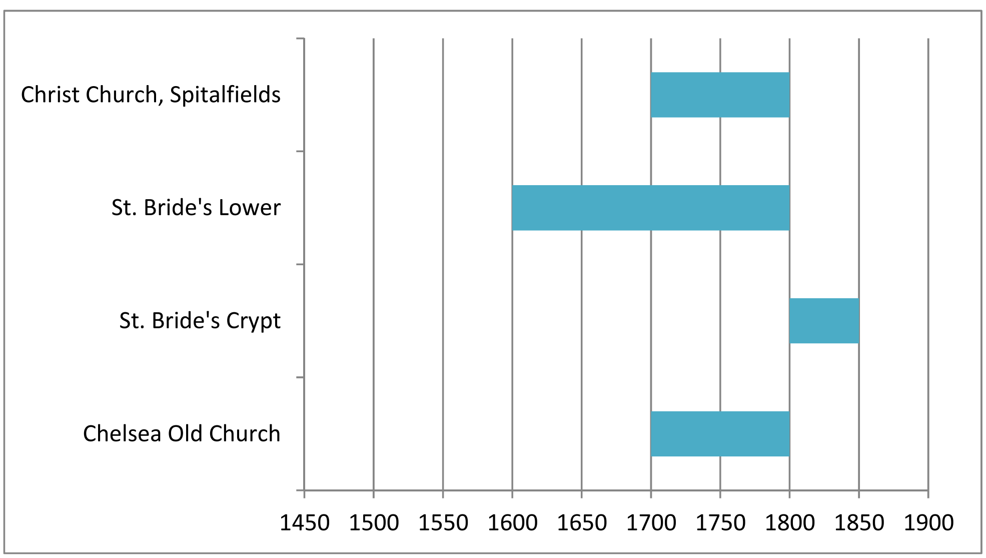


Figure 6.12: The dates of use for the post-medieval cemeteries, based on historical documentation

There is only one Post Medieval population for which a TPR for chronic maxillary sinusitis has been calculated (see Figure 6.12) The prevalence rates for chronic maxillary sinusitis at Chelsea Old Church (χ^2=25.435, p<0.001), St. Bride's Crypt (χ^2=9.464, p=0.002) and St. Bride's Lower (χ^2=57.193, p<0.001) were all significantly higher than at Christ Church, Spitalfields, a middle class population also from Post Medieval London (Molleson and Cox 1993, Roberts 2007). This is surprising given that the three samples with which the population is compared represent both high and low social status as well as urban and semi-rural populations. It would be expected that Christ Church, Spitalfields would be most similar to St. Bride's Crypt, which was a high status urban population in the same city, although St. Bride's Crypt was in use slightly later than Spitalfields. If air quality is a primary cause of chronic maxillary sinusitis, it is possible that the difference in locations of these two sites explains the differences in exposure, but they were not located very far apart.

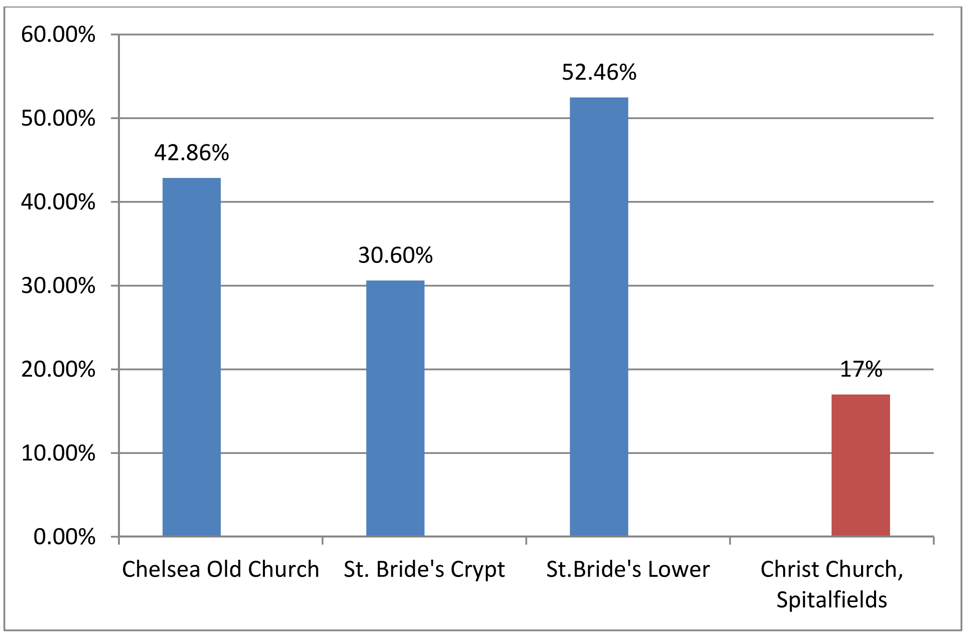


Figure 6.13: The TPR of individuals with chronic maxillary sinusitis from the populations examined in this study (blue) and the post medieval population examined by Roberts (2007) (red)

Roberts and Cox (2003) give two prevalence rates, in addition to Christ Church Spitalfields, for chronic maxillary sinusitis in the Post Medieval Period. Brickley *et al* (1999) recorded two individuals with chronic maxillary sinusitis (1.35% of 148 individuals) from Red Cross Way, London. Conheeney and Waldron (In Press) reported one individual with chronic maxillary sinusitis (0.19% of 533 individuals) from St Brides Lower Churchyard. This differs considerably from the 64 individuals with chronic maxillary sinusitis recorded as present in this study. It is possible that during this previous analysis, there was no specific intention to record this condition, but particularly severe examples drew the attention of the researcher and were recorded.

There do not appear to be any other populations from England for which TPRs of rib periostitis have been recorded. In Figure 7.14, three crude prevalence rates of rib periostitis, compiled by Roberts and Buikstra (2003) are given. Based on the CPRs, the three higher status populations appear to have the three highest prevalence rates of rib periostitis, which is counterintuitive, but could reflect a better state of health which allowed them to suffer from these conditions chronically rather than dying quickly before lesions had occurred.

However, as with the previous period, using the TPR data, St. Bride's Lower had a higher rate than either Chelsea Old Church or St. Bride's Crypt. Therefore, the CPRs given in Figure 6.14 probably do not represent the real relationship between environment or status and the prevalence of rib periostitis.

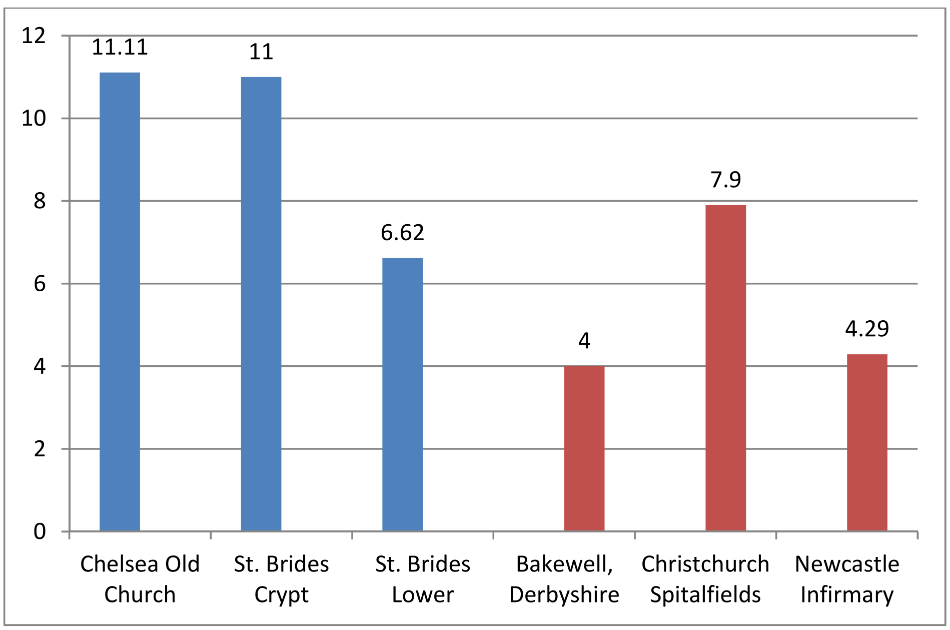


Figure 6.14: The CPR for individuals with rib periostitis in the Post Medieval Period for the populations from this study (blue) and previously analysed populations (red)

The populations from the Post Medieval Period provide the greatest contrast between high and low social status in this study. The individuals buried in St. Bride's Lower churchyard were all of low status and included some individuals from the workhouse and prison (Kausmally 2008). The individuals buried in St. Bride's Crypt would have had to have been buried by individuals with the money to afford such a burial. Since these individuals were named, it is possible to gather some information about their occupation and lifestyles. There is notably one individual from St. Bride's Crypt who spent his last days in a workhouse, but was given a high status burial by his family who had the means to afford it. This does indicate that while the vast majority of people given high status burials probably lived a life of more comfort, there were exceptions (Scheuer and Black 1995; Scheuer and Bowman 1995).

When only the populations examined in this study are included, the high status population, St. Bride's Crypt, has the lowest prevalence rate for chronic maxillary sinusitis, while the lowest status population, St. Bride's Lower, has the highest prevalence rate. The more middle-class Chelsea Old Church, in spite of its semi-rural location, falls in the middle. The location of Chelsea Old Church, on the edge of London, would have allowed its population to travel with relative ease into the city centre. It is probable that the population spent a significant amount of time in the city centre, which could account for its similarity to the urban populations, assuming that the general atmospheric pollution of industrial London was primarily responsible for the rates of chronic maxillary sinusitis in these populations (Cowie *et al*. 2008). It can also be assumed that all these populations used roughly the same fuels. However, higher status individuals might have been able to afford cleaner burning coal, had better stoves and chimneys, with more living space in the home for particulates to disperse, and fewer people in the space to spread infection (Brimblecombe 1987). Higher status housing may also have been built better, allowing for more ventilation. However, laws dictated what materials could not be used for urban housing to decrease the risk of fire spreading, but also lowering ventilation across all social groups (Brimblecombe 1987).

We can obtain a general view of the rates of certain respiratory conditions because records of causes of death were kept in this period. In general, the rates of respiratory disease in these records and the rates recorded by bioarchaeologists are significantly different. The rates would be expected to be lower in the archaeological record, perhaps due to the osteological paradox (Wood *et al* 1992). A condition must be chronic in order for lesions to occur on the skeleton. While it is possible that an individual may die of this chronic condition it is also possible that the individual will contract a disease or develop an acutely fatal condition while still suffering from the original chronic condition. In this case the acute condition would be recorded as the cause of death. Alternatively, acute illnesses, which are quickly fatal leaving no lesions, are more likely to be recorded as a cause of death but do not leave any lesions on the skeleton. Similarly, the historical records may not be accurate if the cause of death was recorded incorrectly. The causes of death recorded may describe multiple conditions, or not be recognizable as a disease recorded in living populations (Ogle 1892; Woods 2006). In the case of St. Bride's Crypt, there were three individuals whose causes of death were reported as various forms of respiratory disease. However, none of these exhibited pathological changes on their ribs/sinuses.

There are also numerous records pertaining to London during this period, unlike in the previous periods. These include historical writings, bills of mortality, climate records, and legal documents. In particular, there are many accounts of laws regarding poor air quality affecting the health of the population, making it difficult to breathe (Brimblecombe 1987). There are also accounts of high rates of respiratory diseases such as tuberculosis (Matossian 1985), which could also account for lesions seen on the visceral surfaces of the ribs as a result of inflammation of the lungs (Roberts and Buikstra 2003). It is likely that tuberculosis is responsible for at least some of these lesions, although, because these lesions are not specific to tuberculosis, without the pathognomonic indicators that appear later in the disease there is no way to determine how many of these individuals suffered from tuberculosis and how many suffered from other conditions. In spite of both types of accounts the prevalence of rib periostitis are not as high as would be expected given the living conditions and the prevalence of respiratory infections recorded contemporaneously. This could also be attributed to the osteological paradox (Wood *et al*. 1992) and the unlikelihood of forming lesions on the bones in acute stages of disease. However, this would not be the case if poor air quality was the primary cause of these lesions because this was unlikely to be acutely fatal.

It is possible, if air quality was the primary cause of these lesions, that the low rates of rib periostitis reflect the use of chimneys in houses for ventilation, which were not commonly used in any of the previous periods, before coal became a common fuel. Unfortunately, as with chronic maxillary sinusitis, it is extremely difficult to determine whether either infection or inhalation of poor quality air (or both) were responsible for the lesions seen on the ribs, as both would have been more likely to affect the lower status groups than the higher status groups. Even the population from Chelsea Old Church, in spite of its rural location, cannot have poor air quality ruled out as the cause of rib periostitis because the population might have spent significant periods of time in central London, and the cemetery population included poorer individuals whose occupations could have exposed them to poor air quality even outside of the city centre (Cowie *et al*. 2008). It is possible that in Chelsea where population density was lower, the rate of infection would also likely be lower, which could, to some extent, rule out infection as a primary cause, at least in this case.

6.2.7 Respiratory disease outside of England

Unfortunately, outside England, there have also been very few populations for which prevalence rates for chronic maxillary sinusitis have been recorded. So few populations have been examined for rib periostitis outside of the context of tuberculosis that these lesions will not be discussed further in this chapter, beyond the possible causes. As referenced in Section 2.2.2.2.1, only one site in Europe, outside of England, had a TPR for chronic maxillary sinusitis recorded. Sites in Maastrict in the Netherlands were analysed by Panhuysen (1997). Data from three relatively rural and high status groups were pooled together (see Figure 6.15). Roberts and Cox (2003) also give CPRs for three sites from Ireland, which are also given below. Power (1994) found one individual with chronic maxillary sinusitis at St. Peter's Church, Waterford (0.35% of 287 individuals). Mullins (Forthcoming) also only recorded one individual from St. Francis' Abbey, Limerick (0.22% of 451 individuals). O'Donnabhain and Cosgrave (1994) found two individuals with chronic maxillary sinusitis at Temple Lane, Dublin (3.39% of 59 individuals) (see Figure 6.15).

In addition, there have been eight populations examined from North America, which were described in Section 2.2.2.2.2 and are represented in Figures 6.15 and 6.16 below.

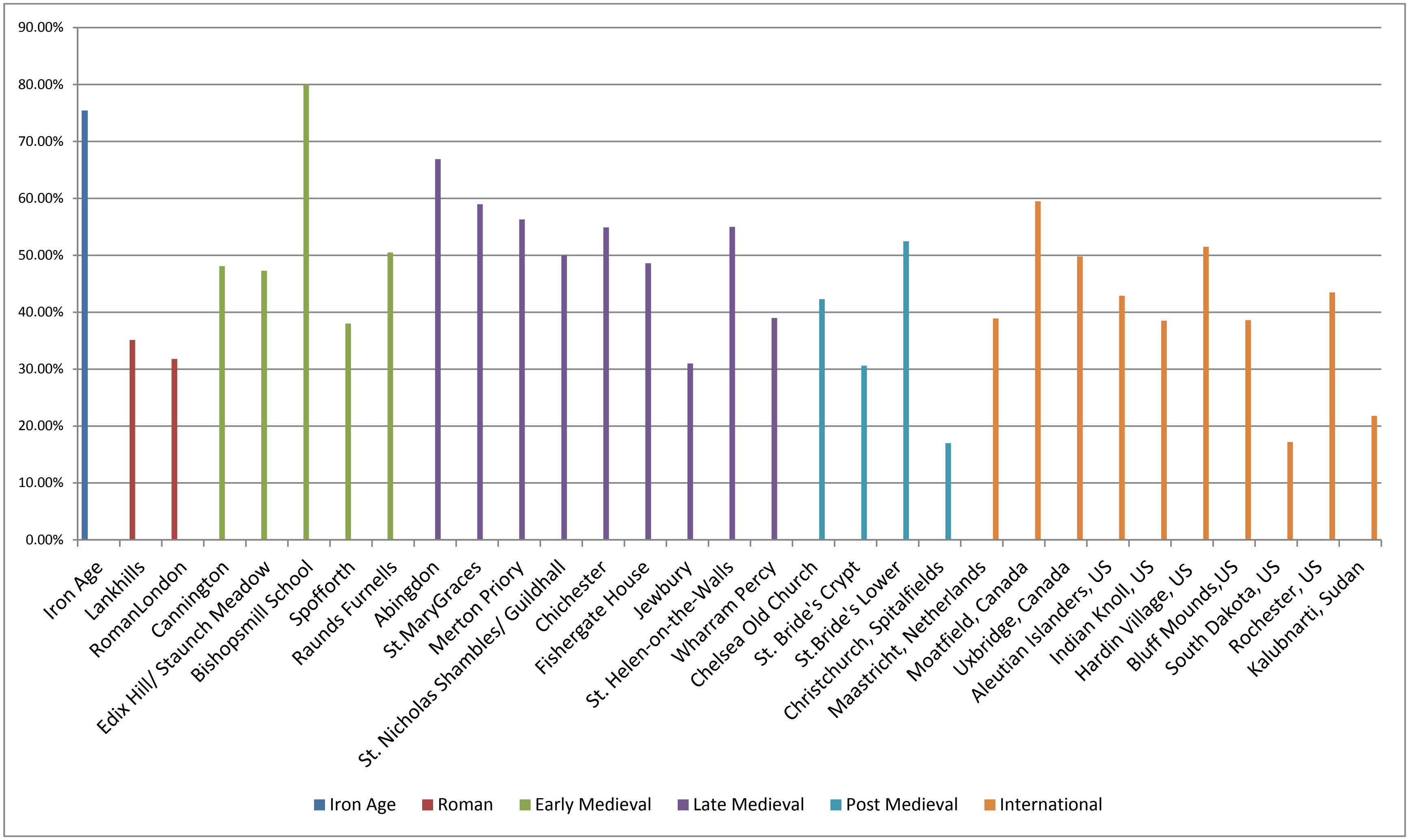


Figure 6.15: TPR for chronic maxillary sinusitis from England and elsewhere.

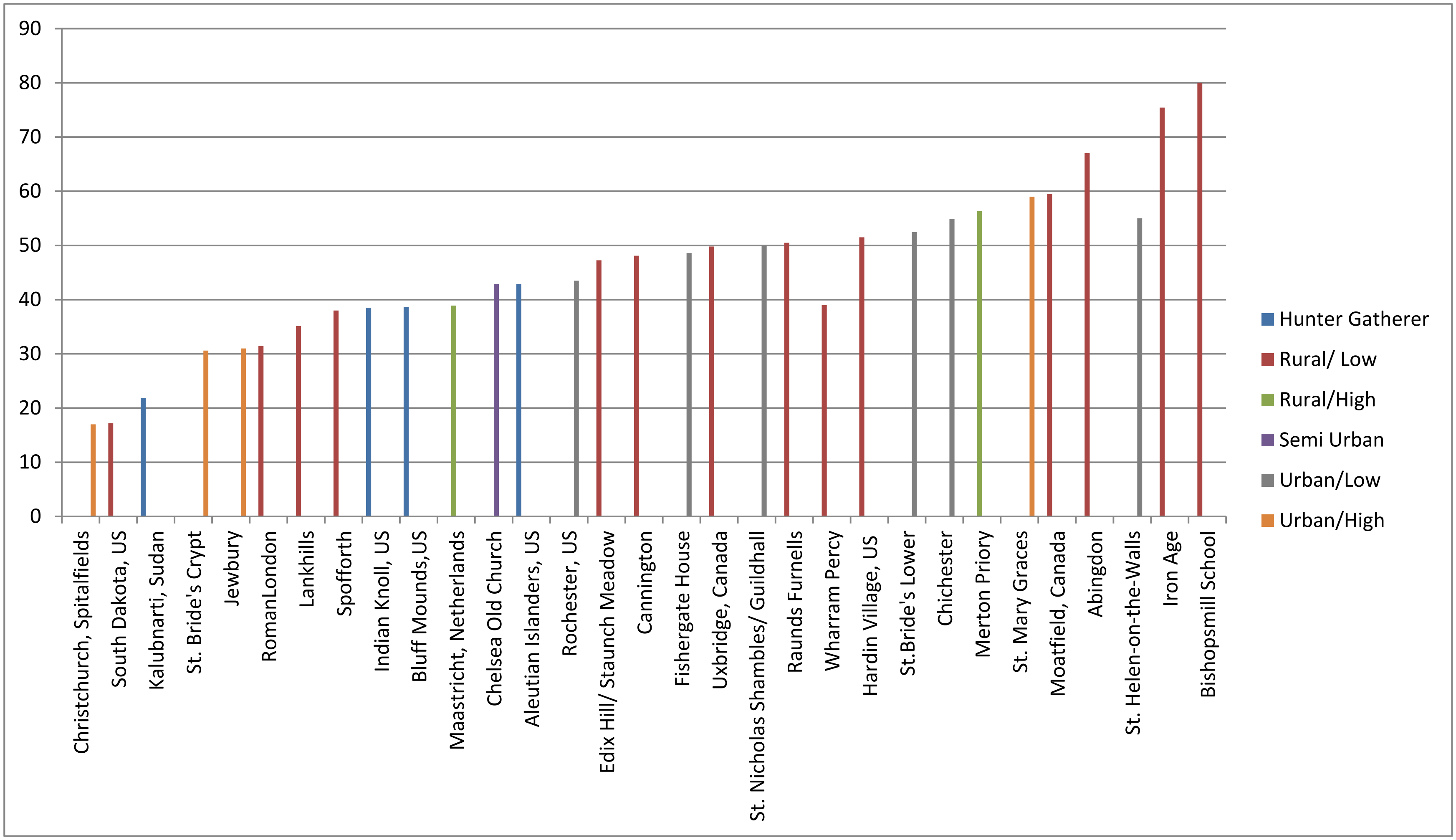


Figure 6.16: The prevalence of individuals with chronic maxillary sinusitis for all of the populations analysed in this and previous studies, arranged by increasing prevalence, environment, status and economy

	IA	LA	RL	CA	EM	BS	SP	RF	AV	MP	MG	LM	HW	FG	CH	WP	SBC	SBL	COC	CS	MA	MO	UX	AI	IK	HV	BM	SD	KU
IA		21	8.659	12.1	9.4	0.3	2.6	2.4	2.47	5.7	4	6.7	7.37	2.8	1.6	26.9	32.7	8.5	4.02	39.3	2.5	0.005	1.8	2.4	5.8	1.1	4.9	19.7	16.8
LA			0.099	5.8	3.3	4.9	0.2	1.6	6.06	10.8	11.6	3.8	7.9	1.3	2.7	0.029	0.02	8.3	0.36	6.7	1.3	4.9	1	0.3	1	1.04	0.08	4	2.1
RL				2.43	1.52	18.5	1.34	6.9	8.72	4.45	4.72	1.68	12.6	5.7	11.4	0.598	0.02	3.558	0.9	10.2	1.12	1.3	8.05	1.3	0.7	3.99	0.78	5.02	2.4
CA					0.01	8.5	0.1	0.3	2.66	1.6	2.3	0.04	1.24	0.002	0.4	4.08	8.5	0.5	0.25	25.01	0.004	2.1	0.004	0.1	0.8	0.04	0.6	10.9	8.2
EM						7.5	0.1	0.2	1.6	1.2	1.8	0.07	0.78	0.009	0.3	1.619	4.7	0.4	0.12	13.4	0.01	1.7	0.01	0.06	0.4	0.05	0.4	7.8	5.5

	IA	LA	RL	CA	EM	BS	SP	RF	AV	MP	MG	LM	HW	FG	CH	WP	SBC	SBL	COC	CS	MA	MO	UX	AI	IK	HV	BM	SD	KU
BS							8.9	7.2	1.7	1.1	0.7	1.3	4.9	2.1	1.3	13.7	7.8	1.6	10.8	23.8	2	0.04	1.6	2.1	4.3	1.1	3.83	15.2	12.4
SP								0.8	6.9	0.7	0.9	0.2	1.28	0.2	0.7	0.037	0.7	0.4	0.003	6.6	0.2	2.1	0.2	0.004	0.05	0.2	0.04	4.7	2.9
RF									6.9	0.2	0.4	0.001	0.39	0.02	0.1	3.334	4.3	0.03	1.2	25.2	0.02	1.6	0.01	0.2	1.1	0.004	0.9	11.5	8.8
AV										0.67	0.3	0.92	5.05	8.5	4.1	8.1	12.6	1.43	3.49	1266	21.1	1.2	10.1	6.9	19.9	2.7	15.4	53.3	48.1
MP											0.1	0.5	0.02	1.2	0.04	7.8	15.8	0.3	1.17	31.5	0.3	0.8	0.2	0.6	2.2	0.07	1.8	14.1	11.3
MG												0.9	0.24	1.9	0.3	8.5	16.4	0.8	1.42	56.2	0.5	0.5	0.4	0.8	2.5	0.1	2.1	14.2	11.4

	IA	LA	RL	CA	EM	BS	SP	RF	AV	MP	MG	LM	HW	FG	CH	WP	SBC	SBL	COC	CS	MA	MO	UX	AI	IK	HV	BM	SD	KU
LM													0.14	0.02	0.3	1.169	5.1	0.1	0.24	12.1	0.005	1.1	0.003	0.1	0.6	0.005	0.5	7.7	5.4
HW														0.885	0.01	11.16	19.3	0.08	3.15	101.07	7.69	0.348	0.907	1.281	6.56	0.025	5.04	34.9	30
FG															0.3	2.26	3.6	0.1	0.7	23	<0.0001	1.9	0.001	0.1	0.8	0.03	0.7	10.6	7.9
CH																7.85	6.5	0.05	3.1	34.3	0.2	1	0.1	0.5	2.1	0.04	1.7	14.3	11.5
WP																	1.4	7.7	0.5	42.3	0.0	8.54	4.53	0.037	0.03	1.28	0.0	13.6	9.45
SBC																		13	1.4	9.5	3.3	8.5	2.4	0.9	0.8	2.3	0.6	3.0	1.3

	IA	LA	RL	CA	EM	BS	SP	RF	AV	MP	MG	LM	HW	FG	CH	WP	SBC	SBL	COC	CS	MA	MO	UX	AI	IK	HV	BM	SD	KU
SBL																			0.69	57.2	0.09	1.35	0.05	0.3	1.5	0.003	1.3	12.8	10.1
COC																				25.4	0.2	4.5	1.3	0.003	0.4	0.8	0.2	12.5	8.7
CS																					20.4	28.1	13.4	7	1.1	11.2	8.8	0.02	0.5
MA																						1.7	<0.0001	0.1	0.8	0.02	0.6	10.1	7.4
MO																							1.3	1.9	4.3	0.8	3.7	16.2	13.3

	IA	LA	RL	CA	EM	BS	SP	RF	AV	MP	MG	LM	HW	FG	CH	WP	SBC	SBL	COC	CS	MA	MO	UX	AI	IK	HV	BM	SD	KU
UX																								0.1	0.6	0.02	0.5	8.1	5.7
AI																									0.08	0.2	0.08	5	3.1
IK																										0.7	<0.001	5.8	3.5
HV																											0.6	7.5	5.3
BM																												5.1	3.1
SD																													0.4

Table 6.3: The chi-squared results for the comparison of all populations for which TPRs are available. Significant results are shown in red. (IA is Iron Age, LA is Lankhills, RL is Roman London, CA is Cannington, EM is the Early Medieval combined sample, BS is Bishopsmill School, SP is Spofforth, RF is Raunds Furnells, AV is Abingdon Vineyard, MP is Merton Priory, MG is St. Mary Graces, LM is the late medieval combined sample, HW is St. Helen on the Walls, FG is Fishergate House, CH is Chichester, WP is Wharram Percy, SBC is St. Bride's Crypt, SBL is St. Bride's Lower, COC is Chelsea old Church, CS is Christ Church Spitalfields, MA is Mastricct, MO is Moatfield, UX is Uxbridge, AI is Aleutian Islanders, IK is Indian Knoll, HV is Hardin Village, BM is Bluff Mounds, SD is South Dakota and KU is Kulubnarti.)

It is clear from Figures 6.15 and 6.16 that the populations examined outside of England, in spite of their different climates, and in some cases different subsistence methods including hunting and gathering, have chronic maxillary sinusitis frequency rates within the same range as those found in England, and even just within southern England. Populations from similar environments, as was also found in this study, did not have more similar prevalence rates for chronic maxillary sinusitis than populations from different environments. The average for all the populations is 46% and the median is 48%.

The only consistent groupings were the high status urban populations if the population of St. Mary Graces is left out, as it was not strictly high status. All the high status populations are English and have among the lowest prevalence rates. Aside from this group, no other subsistence economy or social status group had populations with prevalence rates more similar to each other than any other populations. The populations from Kulubnarti and South Dakota are also among the lowest prevalence rates. While these populations share an agricultural economy, so do many of the populations throughout the range of prevalence rates (Roberts 2007). In the case of Kulubnarti, the low prevalence could be attributed to the relatively warm and dry environment. However, this does not explain the low rate in the agricultural populations from South Dakota (Roberts 2007). This also does not explain the significant difference between South Dakota and any of the other agricultural populations from North America.

Bluff Mounds (also referred to as Illinois in Roberts 2007), Indian Knoll, and the Aleutian Islanders are all representative of hunter-gatherer groups from various parts of the United States (Roberts 2007). It could be assumed that these population would be exposed to lower concentrations of pollutants in the air, given that their settlements were relatively temporary compared to sedentary agriculturalists, and they did not keep livestock, which would have exposed them more frequently on a daily basis to animal dander (Roberts 2007). However, while these populations were on the lower end of the range of prevalence for these populations, they were not the lowest. This could be accounted for by exposure to smoke in the home as well as exposure to particulates, such as plant matter or fungi in the air, while foraging or performing other daily activities. It is also possible that these differences in climate or lifestyle are responsible for the higher prevalence of chronic maxillary sinusitis in these populations than in the agricultural populations with lower prevalence rates. Climate, vegetation, contact with animals, and other differences in lifestyle, environment and activity could also account for the wide range of prevalence rates amongst agricultural populations.

However, if differences in climate or housing on this scale are not large enough to create significant differences in the prevalence of chronic maxillary sinusitis, does environment and lifestyle have the effect we believe it has on the respiratory system? The only way to account for these differences is by including other factors, such as dental disease and infection, or by speculating on lifestyle factors that are not visible in the archaeological record, such as time spent indoors.

6.3 Do chronic maxillary sinusitis and rib periostitis have a common cause?

Before it is possible to discuss the potential causes of the conditions that led to these osteological lesions, it is necessary to determine whether there is any relationship between the two lesions seen in the skeleton. If the lesions appear to be related, then the cause of the lesions could be the same. This would direct the remainder of this chapter differently than if there is no apparent relationship between the prevalence of the lesions. In that case, the sinus lesions and rib periostitis would be examined separately and it would be expected that they have different causes.

As discussed statistically in Section 5.6 and as seen below in Figures 6.17 and 6.18 there does not appear to be any correlation between the prevalence of chronic maxillary sinusitis and rib periostitis, even when individuals with visible maxillary dental disease are removed from the sample. This would suggest that either the causes of these lesions are different, or that they are affected by the same cause differently. If these lesions are both caused by infections however, it is also possible that the lack of correlation between the prevalence of the lesions is a result of one condition being affected to a larger extent than the other by the osteological paradox (Wood *et al* 1992). This is possible if the lesions in the sinuses or ribs are caused by a potentially acutely fatal condition, while the other is never acutely fatal. For example, if chronic maxillary sinusitis lead to pneumonia, as a result of inhaling post nasal drip, and the pneumonia was acutely fatal, the sinus may show lesions as a result of the chronic inflammation, while the ribs would show no lesions, since death shortly preceded the onset of the pneumonia (Ozbay and Arslan 2002). However, if they originated at the same time, for example, as a result of a systemic infection or exposure to poor air quality, then neither type of lesion would have time to develop before death.

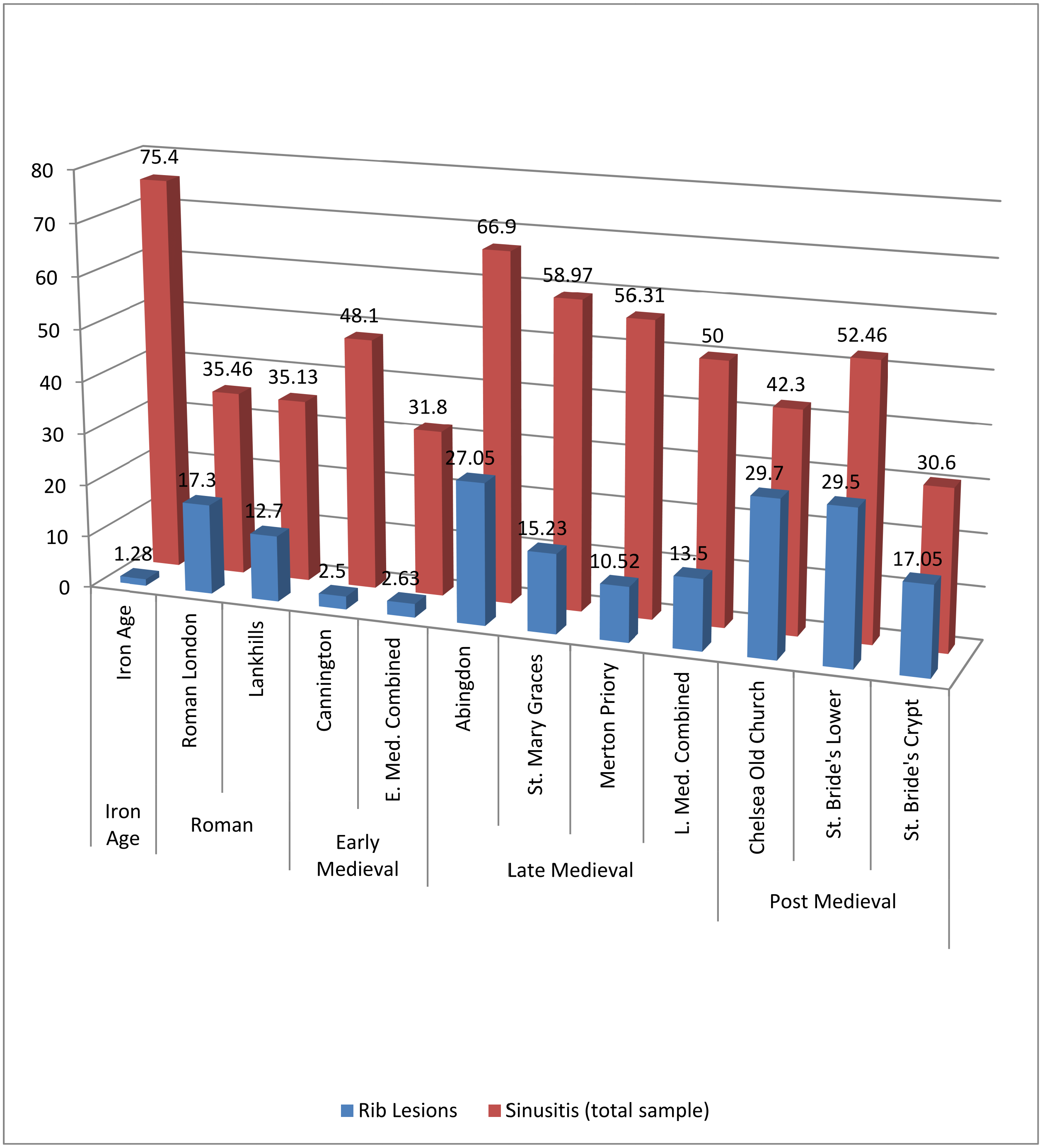


Figure 6.17: A comparison of the TPR by individuals for chronic maxillary sinusitis and rib periostitis.

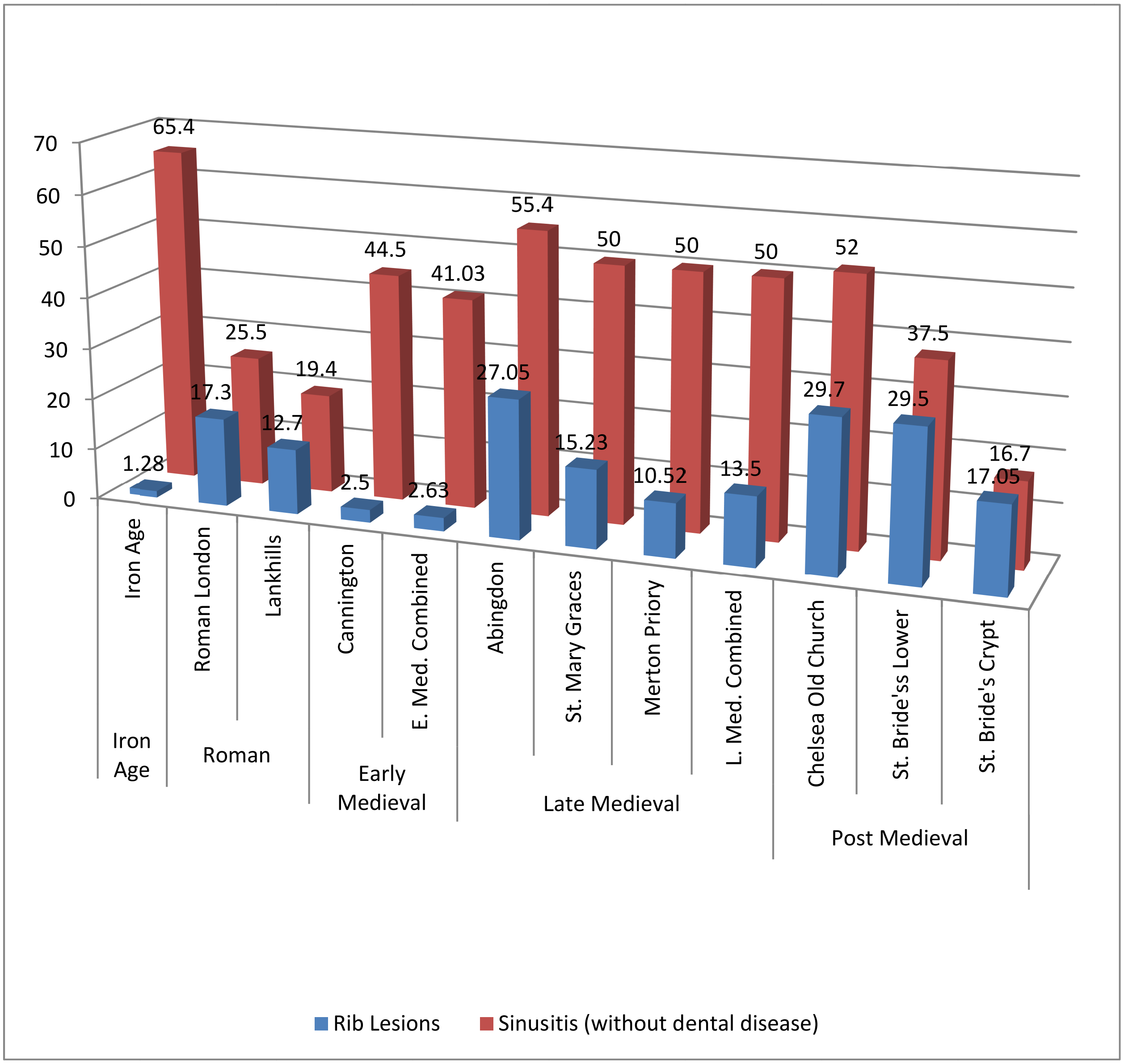


Figure 6.18: Comparison of the TPR by individuals, for rib periostitis, and the rates for chronic maxillary sinusitis only in individuals without any visible maxillary dental disease

The lesions could also appear not to correlate if individual populations experienced more acute forms of infection or had weaker immune systems. Using the same example, if there are two populations where a percentage of one of them develops pneumonia after having suffered from chronic maxillary sinusitis, but the other is generally healthier, the population with poorer health might have significantly less evidence of rib periostitis. In the population with poorer health the individuals were more likely to die soon after developing the condition, while in the healthier population the individuals might have suffered with the condition long enough for rib periostitis to develop. In this case, the cause would be the same, but when comparing populations there would be no correlation. There is also the possibility that both conditions are frequently, but not always, due to the same cause. Given that there are a large number of causes of chronic maxillary sinusitis that do not affect the lower respiratory system this could account for the lack of correlation. For example, if the majority of cases of chronic maxillary sinusitis and inflammation in the lungs are caused by poor air quality, but one population also has a large amount of dental disease that is causing a much higher rate of chronic maxillary sinusitis than rib periostitis, there would appear to be no correlation between the two conditions when looking at these populations. However, even when individuals with visible dental disease are removed there is no apparent correlation (see Figure 6.18).

Given this lack of correlation, it seems unlikely that the same factors are responsible for the prevalence of both these conditions. On this basis, the causes of the two forms of lesions will be discussed separately in the remainder of the chapter.

6.4 Respiratory disease and air quality as shown in sinuses and ribs

As discussed in Chapter 2, there is ample evidence to link poor air quality to respiratory disease in living populations (Bruce *et al*. 2000; Smith *et al*. 2004; Usinger 1994; Venners *et al*. 2001; World Health Organisation 2006).

The sites examined in this study were divided chronologically into five time periods. For the most part this does not help to contrast air quality. Many of the factors that affect air quality would not be unique to a particular time period, but continue between them and change, even multiple times, within them. Housing styles will also not be unique to a particular time period, but gradually change through time as they gain in and fall out of popularity. However, some types of housing may dominate a particular time period, which allows some comparison. For example, round houses were common in the Iron Age, while non-flammable building materials, such as stone and tiles, were legislated for, and therefore were ubiquitous in the cities in the Post Medieval Period (Brimblecombe 1987; Cunliffe 2004). Similarly, climate, which will be discussed further below, affects the concentration of particulates in the environment such as pollen or smoke and the amount of time people are exposed to them

(Waddy 1952). These changes in climate would not be limited to the beginning or end of time periods, which were assigned based on major political or social events.

The samples were divided into urban and rural for the Late Medieval Period, Post Medieval Period, and to some extent in the Roman Period based on the relative population density and predominant occupations, as discussed in Section 1.1. The air quality in the urban and rural locations would depend on a number of factors. The rural populations, presuming they engage in activities such as agriculture, or other activities that affect air quality, such as baking, making pottery or metalwork, would have been exposed to high concentrations of particulates such as dust, pollen, fungus, and possibly animal dander (Dyer 2000; Giles and Dyer 2005). However, due to the larger amount of space around the home, a rural household would not be exposed to the added particulates from nearby homes and could have more, and larger, windows for added ventilation (Gies and Gies 1990). In the urban environment there would generally be higher levels of pollution coming from the many homes and businesses in a smaller area. This would also limit the ability to ventilate, as allowing polluted air out also allows polluted urban air in, although the relatively diluted amount of pollution in the atmosphere might have been be preferable to the more concentrated domestic waste. This, as well as the overall size and design of buildings, would limit the number and size of windows in a home (Grenville 1997; Wood 1981). In the Post Medieval Period, the close proximity of buildings increased the risk of fire spreading easily to neighbouring houses and building materials were legally restricted in large cities, such as London, to non-flammable materials such as brick, stone, and tile which, without intentional modifications, would not allow for ventilation (Brimblecombe 1987; Keene 1983; Wood 1981). Homes would also be in close contact with nearby businesses, which might also produce more air pollution, perhaps even sharing the same buildings.

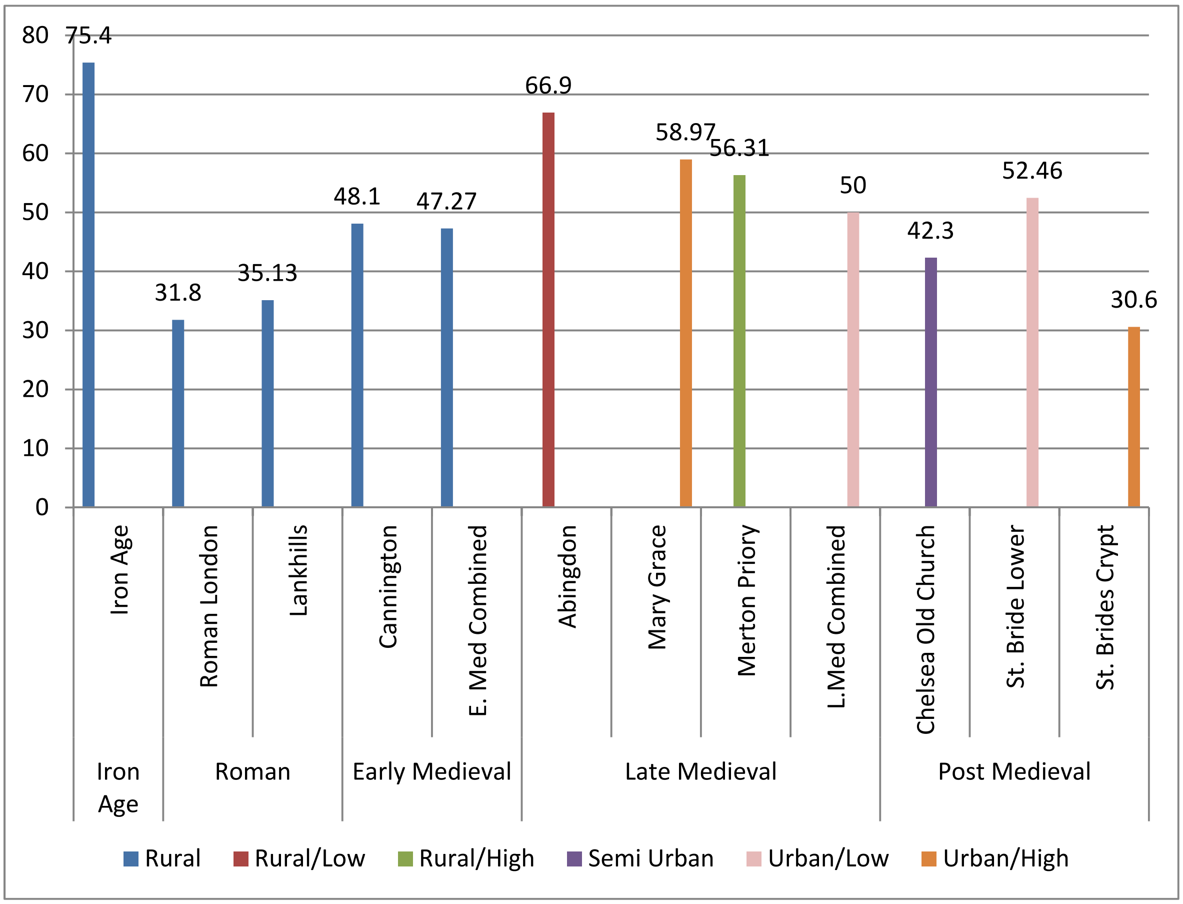
In the Post Medieval Period, when increasingly mechanized industry produced large amounts of pollution, the industries that created the most pollution would be legally limited to areas just outside the city, helping to reduce the levels of industrial pollution in the city centre (Brimblecombe 1987). The households living in these suburban areas would have been exposed to the high concentrations of smoke and other waste while in their homes and perhaps while working in the industry itself. Smaller scale industries, such as baking, would not be excluded from the city centre and likely increased the already high concentrations of pollution in the densely populated city centres (Brimblecombe 1987; Dyer 2000; Grenville 1997; Keene 1983; Schofield and Vince 2003).

It is also expected that the individuals from the lower social status populations would be exposed to poorer air quality than those in higher status populations. Lower status populations would not be able to afford the more expensive cleaner fuels, lived in smaller homes with less space per person in less desirable areas of the city (Brimblecombe 1987; Keene 1983; Olsen 1999). Wealthier individuals could afford larger, better built homes, better cleaner fuels in better designed stoves and fireplaces. They may also have avoided the types of activities such as cooking and cleaning, which would expose them to higher concentrations of particulates (Brimblecombe 1987; Keene 1983; Olsen 1999). Conversely, the lower status individuals might have worked in industries that exposed them to high levels of pollutants, as well as living near these industrial areas (Brimblecombe 1987; Keene 1983; Olsen 1999).

Based on modern clinical data it would be expected that women would suffer more from respiratory disease, unless the men were exposed to high concentrations of pollution in their occupations, given that women spent so much time indoors and around fires. It was surprising, given this established link in living populations, that in so few populations there was any significant difference between the sexes. It is possible that both sexes were exposed to pollution to the same extent in different environments or it is also possible that this demonstrates the lack of impact of air quality on these lesions.

High prevalence rates of chronic maxillary sinusitis or rib periostitis could also point to air quality as a cause since the population would be chronically exposed to a rarely acutely fatal cause, unlike in the case of infection. The individuals would be unlikely to recover, given chronic exposure, but it was also unlikely to lead to death soon after exposure, because the gases and airborne particulates in the environment rarely naturally reach acutely fatal concentrations (Naeher *et al*. 2007), and so the individuals were unlikely to die before bones were affected. While the state of the individual's general health and immune system might affect the extent of an immune reaction to particulates or chemicals that might reach the lower respiratory system, it seems likely that in the case of chronic exposure to poor air quality, the osteological paradox would play less of a role. As a result, a high prevalence of either chronic maxillary sinusitis or rib periostitis could indicate that air quality was a significant cause of these lesions, rather than factors such as infection, which would be unlikely to have such high prevalence rates, because individuals may recover or die quickly after contracting infections, and therefore not develop lesions on the skeleton (Wood *et al* 1992). However, using the samples from this study and those previously analysed, the prevalence rates do not increase or decrease relative to the known or estimated air quality of the period and region. This will be discussed further below.

6.4.1 Chronic maxillary sinusitis and air quality: environment and status



6.19: The prevalence of chronic maxillary sinusitis, calculated as the number of individuals with chronic maxillary sinusitis in one or both sinuses, as a percentage of the number of individuals with at last one sinus partially preserved, for all twelve samples (2 combined): environment and status

As discussed in Chapter 2, there is evidence from clinical studies of individuals in developing countries that shows chronic maxillary sinusitis is associated with poor air quality, particularly in the home (Akunne *et al*. 2006; Bailie *et al*. 1999; Boleji *et al*. 1989; Bruce *et al*. 1998; Bruce *et al*. 2000; Caceres *et al*. 2001; Campbell 1997; Chen *et al*. 1990; Cleary and

Blackburn 1968; Dockery *et al*. 1996; Ekici *et al*. 2005; Ellegard 1997; Ezzati and Kammen 2001; Ezzati and Kammen 2002; Hamada *et al*. 1992; Holt 1996; Ige and Awoyemi 2002; Institute 1995; Mehta 2002; Mishra 2003; Peden 1996; Perez-Padilla *et al*. 1996; Pino *et al*. 1998; Ramakrishna 1988; Reed *et al*. 2006; Saksena *et al*. 2003; Shrestha and Shrestha 2005; Smith *et al*. 1993; Smith *et al*. 2004; Usinger 1994; Venners *et al*. 2001; Yuhui *et al*. 1991). However, there are many differences between the lifestyles of modern populations in developing countries and those that lived throughout much of British history. Similarly, there are many different pollutants in the atmosphere from modern inventions and industries that would not have been a concern for historic populations, which could account for any differences.

For archaeological populations where intact buildings no longer exist, we can estimate relative exposure to indoor pollution based on archaeologically recovered building materials and styles, combined in some cases with knowledge of status and population density. However, it is impossible to know not only how much pollution would have been present in a home or other regularly used buildings, but also how much time the population spent exposed to it for any archaeological population. This limits our ability to positively accept or rule out the link between the frequent exposure to poor air quality and the lesions associated with chronic inflammation.

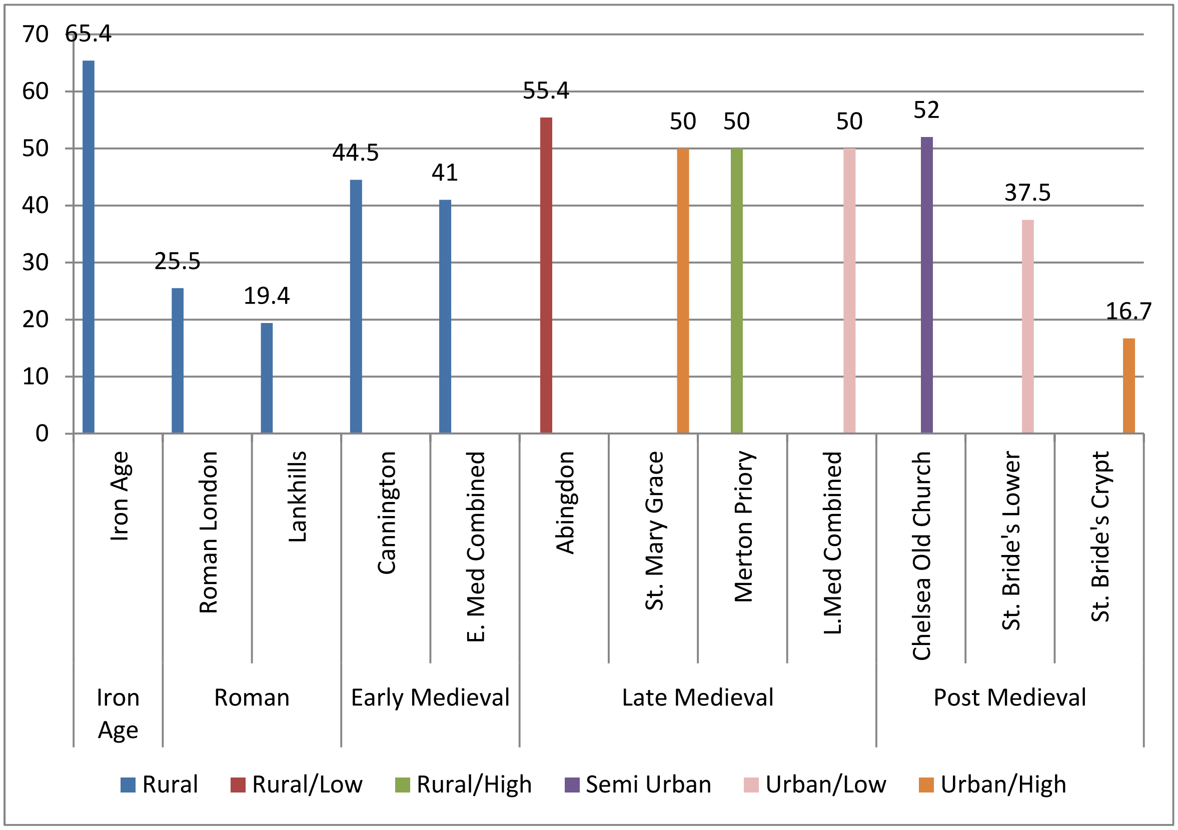


Figure 6.20: TPR of chronic maxillary sinusitis in one or both sinuses in individuals without any severe maxillary dental disease: environment and status

Facial morphology also influences the impact of exposure to poor air quality on sinuses. While it is possible to determine the size and shape of complete sinuses where they are almost completely preserved, it is not possible to determine the size and shape of facial features made of soft tissue, most notably the nostrils, which will determine the amount of air and, by extension, pollutants inhaled at any given time (Bascom and Kesavanathan 1997).

Bioarchaeological studies of chronic maxillary sinusitis have typically concentrated on either individual populations or comparisons of a few populations. While some of these studies have found significant differences that could be attributed to differences in exposure to poor air quality, this has not consistently been the case. Since this research has examined twelve more populations while attempting to limit confounding factors, the hope is that the results from this study would support or disprove the hypothesis that the prevalence of chronic maxillary sinusitis and rib periostitis are correlated with the exposure to air pollution. However, this has not been the case.

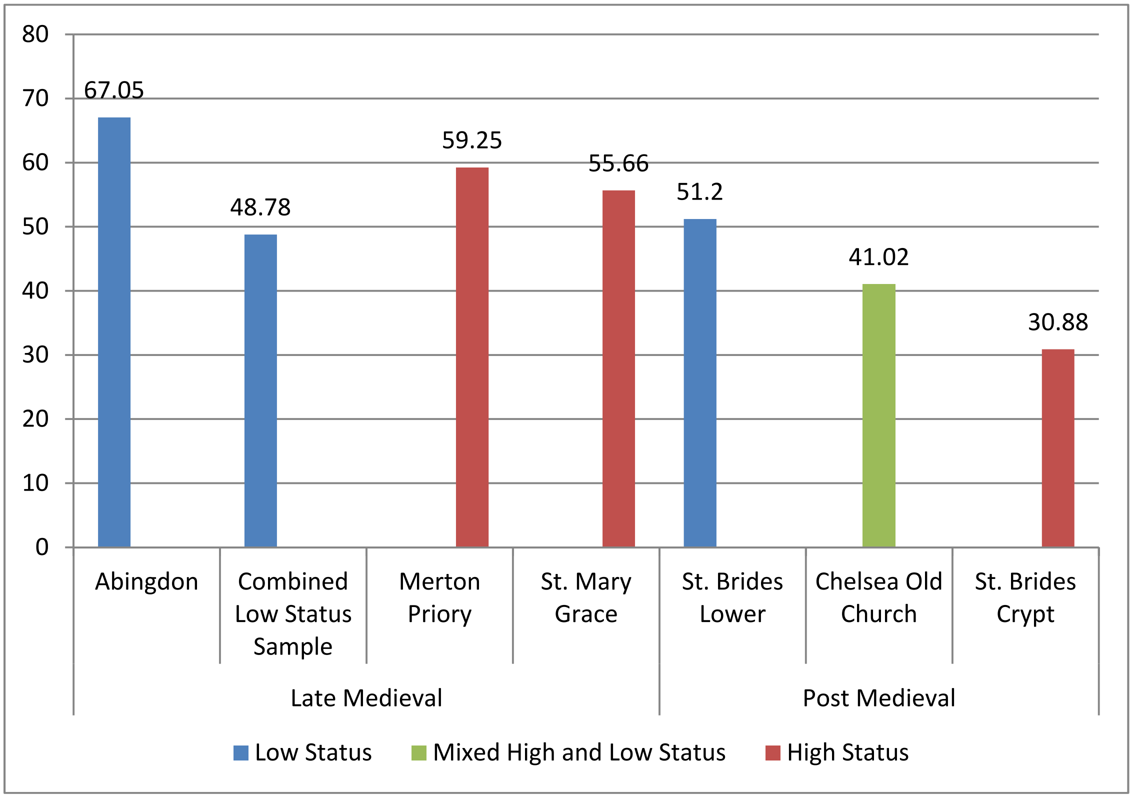


Figure 6.21: TPR of individuals with chronic maxillary sinusitis arranged chronologically for comparison of social status by period

The initial conclusions based on the results shown above in Figures 6.19 ad 6.20 is that poor air quality is not primarily responsible for the lesions observed in the maxillary sinuses in these populations. However, this does not mean that poor air quality can be eliminated as common cause of these lesions in archaeological populations.

Exposure to poor air quality is not dependent on atmospheric pollution alone. As mentioned previously in this study, there are any number of factors that can influence exposure. As is clearly seen in Figures 6.21 and 6.22 where, within the urban/rural groups, the prevalence rates are no more similar to each other than to the other group. However, if only the Post Medieval Period is considered, then there is a relationship between status and the prevalence of chronic maxillary sinusitis, as is visible in Figure 6.22. St. Bride's Crypt and St. Bride's Lower were two populations who lived in the same city at the same time, and represent opposite ends of the social status spectrum; each would most likely have experienced significantly different concentrations of air pollution to the other (Brimblecombe 1987). These data are even more interesting when considering that the Late Medieval high and low social status groups are not nearly as well defined or their designation as high and low status not as well supported by historical records. This supports the theory that only a difference in exposure to poor air quality above a certain point will lead to significant differences in the prevalence of chronic maxillary sinusitis. In this case, only when two population's differences in lifestyle had as large a difference as that found between the two cemeteries from St. Bride's Church was there any significant difference in the prevalence of chronic maxillary sinusitis. This appears to be further supported by the low prevalence of chronic maxillary sinusitis recorded by Roberts (2007) at the relatively high status Christ Church, Spitalfields. However, in order to confirm that these results are not coincidental, more Post Medieval populations would need to be studied and populations who better represented the extreme ends of the social status spectrum for the Late Medieval Period would need to be found.

The prevalence of chronic maxillary sinusitis at Abingdon was not significantly higher than the other Late Medieval populations, with the exception of the low status urban sample made up of St. Nicholas Shambles and Guildhall Yard East. Given that Merton Priory was also predominantly rural from the same period it may be unsurprising that the difference between the populations was not significant, although the part of the population from Abingdon that came from the surrounding countryside would have likely been more exposed to agricultural pollution, such as dust pollen and animal dander. The population buried in Merton Priory cemetery, as mentioned above, might have spent some time in their gardens, in the case of monastic individuals, as opposed to the lay people buried there. However, this discrepancy does not appear to have had an effect on the prevalence of chronic maxillary sinusitis (Allen 1990; Miller and Saxby 2007).

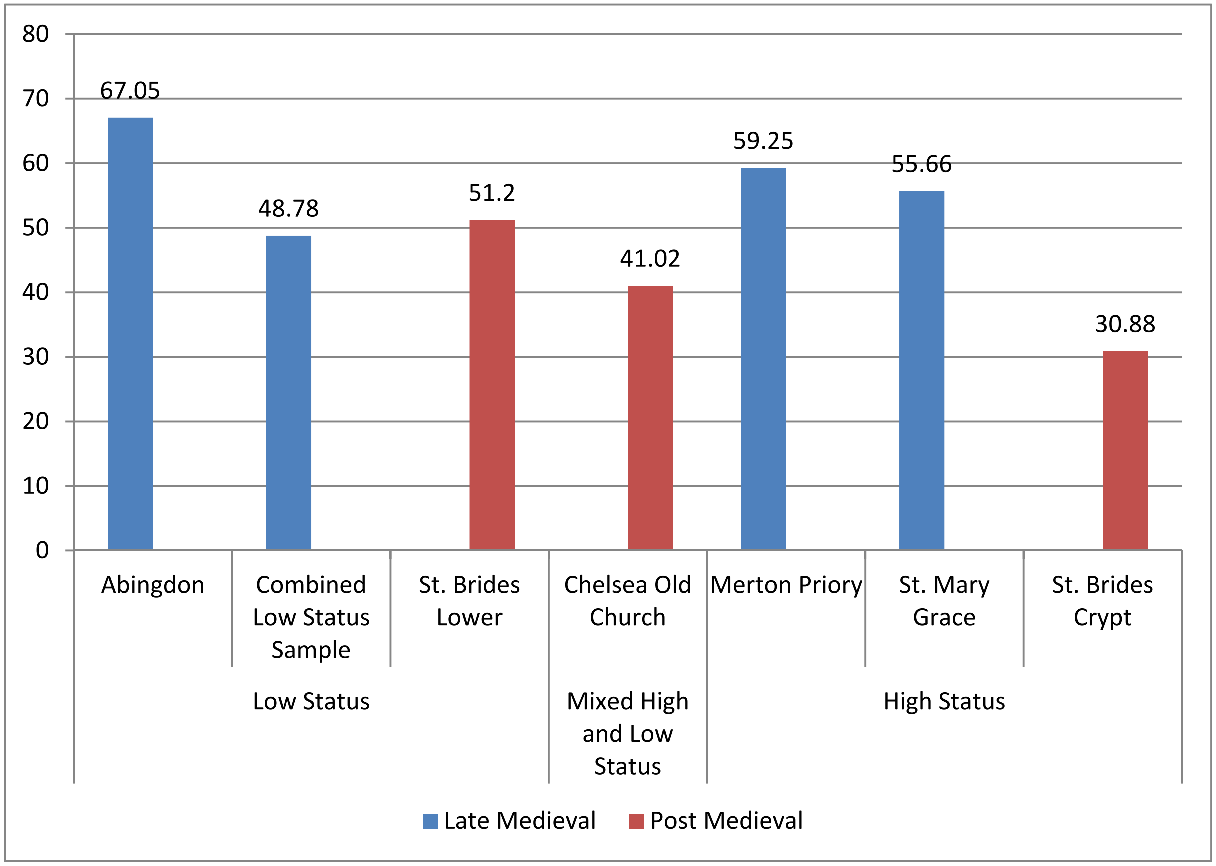


Figure 6.22: The TPR of individuals with chronic maxillary sinusitis, ordered according to relative social status

The population of St. Mary Graces, who would have been more central to London at the same time, and in theory should have been exposed to more pollution as a result of the higher population density, did not have a significantly different prevalence. This could be attributed to their relatively high social status. However, the population was not purely high status, since there was a mixture of status groups buried there (Bekvalac 2008). It is also possible that the environment in London, during this period, and before the Industrial Revolution, did not have significantly worse air quality than more rural areas of the country. Similarly, the low status sample from London, during the same period, was not significantly different to any of the other populations during this period, with the exception of Abingdon. Whether this means that status had little effect on the prevalence of chronic maxillary sinusitis in this period, at least in this region, may need to be investigated. It is likely that the same types of fuels were used by all of these populations from this period regardless of location, using more or less the same technologies, and this could explain the lack of significant differences (Alcock 2006; Blair 2003; Brimblecombe 1987; Cunliffe 2004; Dyer 2000; Grenville

1997; Hamilos 2000; Perring 2002). These differences are shown graphically in Figures 6.22 and 6.23

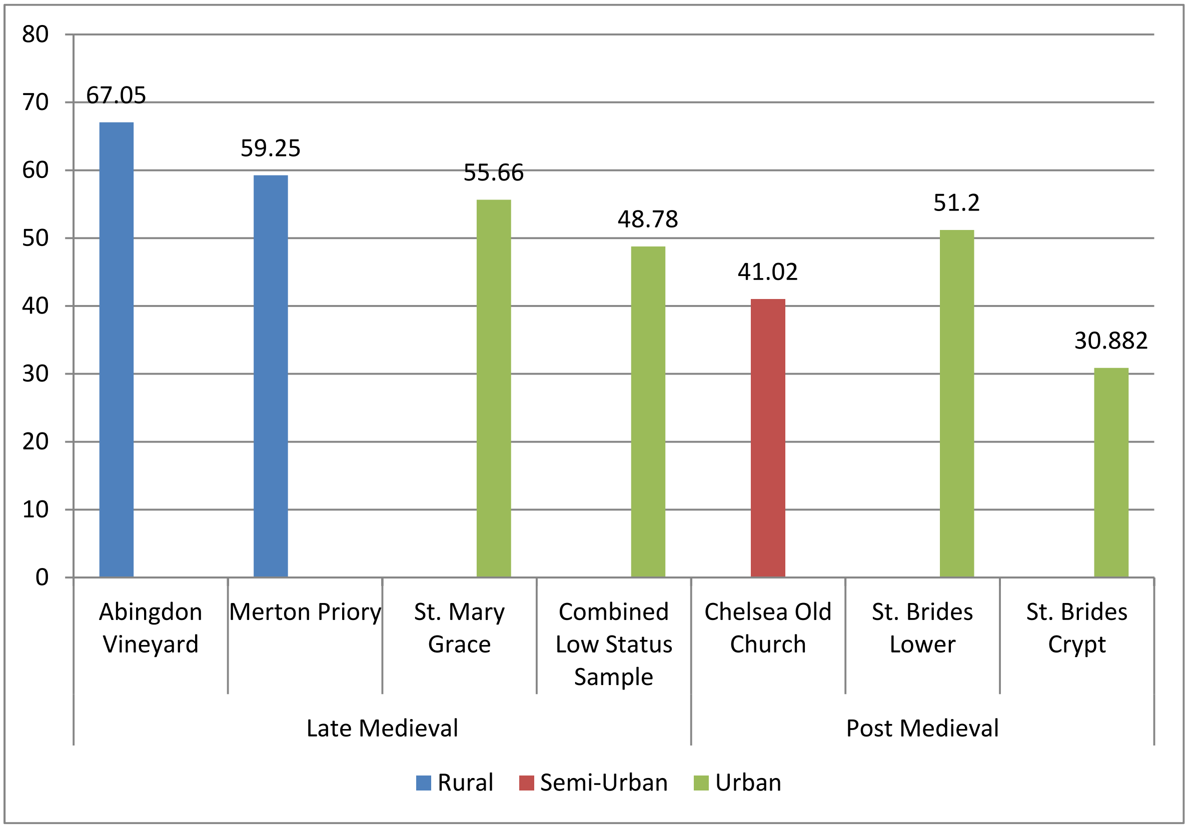


Figure 6.23: The TPR of individuals with chronic maxillary sinusitis, divided chronologically: urban, semi-urban and rural

The only period during which the urban populations had significantly more chronic maxillary sinusitis than the rural populations is during the Post Medieval Period. This is understandable, given that this is the only period where the term "urban" is truly representative of the modern definition. The populations living in London, in the Roman Period, would have lived in a considerably more rural setting than in the Late Medieval Period, which would have been less populated than the Post Medieval Period (Barber and Bowsher 2000; Dyer 1998; Dyer 2000; Giles and Dyer 2005). In the Late Medieval Period, houses in the cities, with the exception of some high status houses, were typically built of the same materials used in more rural areas, wood, wattle, daub, and thatch (Schofield and Vince 2003). It was only in the Post Medieval Period, due to the risks of fire in cities, that the non-flammable materials, which allowed for less ventilation, were legislated (Brimblecombe 1987). Industry was kept out of the cities which would have helped eliminate industrial pollution, until it was so prevalent in the Post Medieval Period that it was carried over all of Southeast England by the wind (Brimblecombe 1987). However, individuals living in both the Late and Post Medieval Period would be exposed to particulate pollution created by daily activities connected with occupation and keeping domestic animals (Brimblecombe 1987; Dyer 2000; Grenville 1997). By comparison, the Post Medieval Populations lived during the Industrial Revolution and were exposed to atmospheric pollution so characteristic of the period, despite laws which limited industrial activity in central London (Brimblecombe 1987; Dyer 2000; Grenville 1997)

Perhaps more interesting than the lack of a rise in the prevalence of chronic maxillary sinusitis in the Post Medieval Period is the relatively high rates in the rural communities. The differences are not significant, with the exception of Abingdon Vineyard, but this seems quite logical. The rural environment would have had high concentrations of particulates in the air, including smoke from fires, dust, pollen, and animal dander, at least to the same extent as or perhaps to an even greater extent than in the urban environments. This seems to be confirmed by the prevalence rates for chronic maxillary sinusitis, which are relatively higher in rural populations than in the urban populations, as was discussed in Sections 6.2.2 6.2.3, 6.2.4, and 6.2.5. Although this theory fits well with the data from this study, when populations that were previously recorded are taken into account, again there are prevalence rates that are not expected. Rural Bishopsmill School is the highest prevalence rate recorded, significantly more so than the nearby rural Spofforth. Given the similarity in lifestyle, the expectation would be that they were exposed to the same types and concentrations of air pollutants and should have similar prevalence rates. Furthermore, rural Wharram Percy is significantly lower than the Late Medieval urban populations examined in this and other studies (See Table 6.2). As with all of the previous problems, do these anomalies falsify the theory, or are there other factors we cannot see or yet understand that lead to the unexpected results?

Assuming that lifestyle and climate changes account for the differences in the amount of time exposed to domestic pollution, this could explain the similarity in the results from all periods, but also the occasional differences, which seem to correspond to time periods at least to a small extent. For example, the prevalence rates for the Early Medieval populations were higher than in the Roman Period. Based on research into palaeoclimate, the Roman Period is known to have been warmer and milder than the Early Medieval Period (Dark 2000; Langdon *et* *al*. 2004). If the population spent more time outdoors in the milder climate, or had less need to light fires in the home for warmth, this could explain the differences in prevalence rates. Climate as a cause of respiratory disease will be discussed further later in this chapter.

This theory, however, does not explain the unusually high prevalence of chronic maxillary sinusitis amongst Iron Age populations, which cannot entirely be attributed to the high rate of severe dental disease. Although the Iron Age was relatively cool compared to the Roman Period, it was not significantly cooler than the Early Medieval Period (Dark 2000). The only way that air pollution could explain the high rates in this period is if either the buildings these populations lived in had particularly poor ventilation relative to the periods that followed, or they spent significantly more time exposed to pollution than in any of the following periods. There is no direct evidence to support this, although there is a great deal that is not known about these populations (Cunliffe 2004; Hey *et al*. 1999; Parfitt 1995). There is also no reason to suspect that the Iron Age houses were significantly less well ventilated than those built in the following periods as, aside from a relatively small number of high status houses, the average home in the proceeding periods used the same or similar building materials to those used in the Iron Age (see Section 3.2) (de la Bedoyere 2001; Hamerow 2002; Perring 2002). It is possible that the style of homes built in the Roman and Early Medieval Periods were responsible for a significant reduction in the concentration of pollutants at head level, for example by building roofs higher and allowing more room for smoke. Given this, exposure to poor air quality does not appear to explain the significantly higher rate of chronic maxillary sinusitis in the Iron Age sample compared to any of the other samples used in this study, unless this population spent significantly more time exposed to high concentrations of pollutants in the home or while carrying out daily activities.

Simply because poor air quality does not fit the aetiological pattern overall, or does not appear to be the cause in chronic maxillary sinusitis frequency in individual samples, does not mean that it is not the cause in any cases, although this may also be true. It is possible that all of the populations were affected by poor air quality and some populations were also affected by other causes such as infection, or dental disease. It could also be the case that there are factors we cannot see in the archaeological record, such as the amount of time spent indoors. It is, however, clear from these results that air quality is not solely responsible for the prevalence of chronic maxillary sinusitis. The lack of significant difference between frequencies in the majority of the sample could be accounted for by the similarity in fuels and technology, while the anomalous case of the Post Medieval Period could be accounted for by new fuels, technology, and the differences in status. However, the Iron Age and Abingdon Vineyard samples' high rates could only be accounted for in either case by factors that are not visible in the archaeological record.

6.4.2 Rib periostitis and air quality

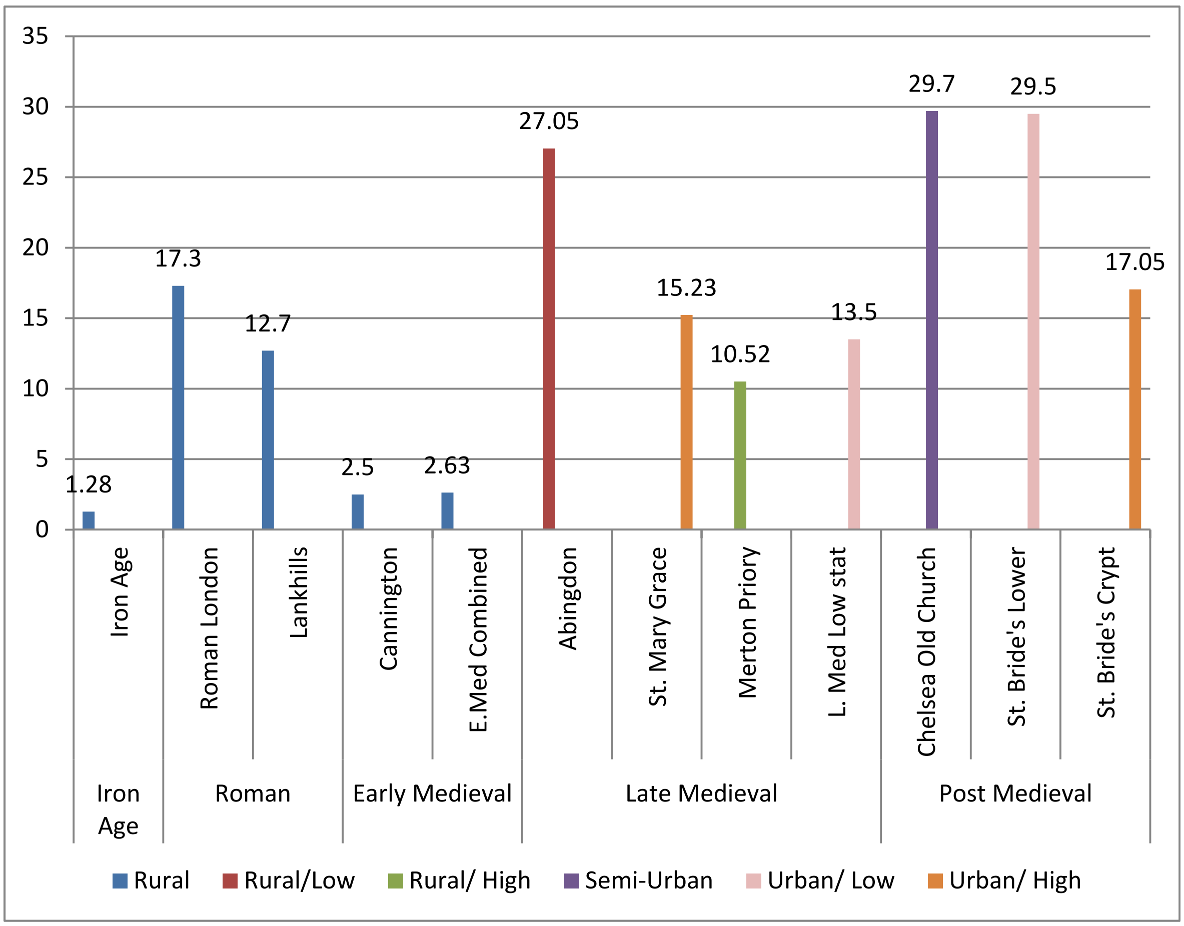


Figure 6.24: The TPR of individuals with rib periostitis (individuals with rib periostitis on at least one rib as a percentage of the number of individuals with at least one rib preserved): environment and status.

As with the prevalence rates for chronic maxillary sinusitis, there is no clear correlation between the prevalence of rib periostitis and the relative atmospheric pollution, estimated based on the historical and/or archaeological evidence. As was shown statistically in Section 5.3, and is easily seen in Figures 6.24 and 6.25, while some of the periods have a lot of similarity in frequency of rib periostitis within them, there is also a lot of similarity across the time periods, and a lot of differences within status groups and environments. Unlike with chronic maxillary sinusitis, the Iron Age and, in this case, the Early Medieval Period populations, have the three lowest prevalence rates calculated. Abingdon, in spite of its Late Medieval rural setting is among the highest prevalence rates recorded.

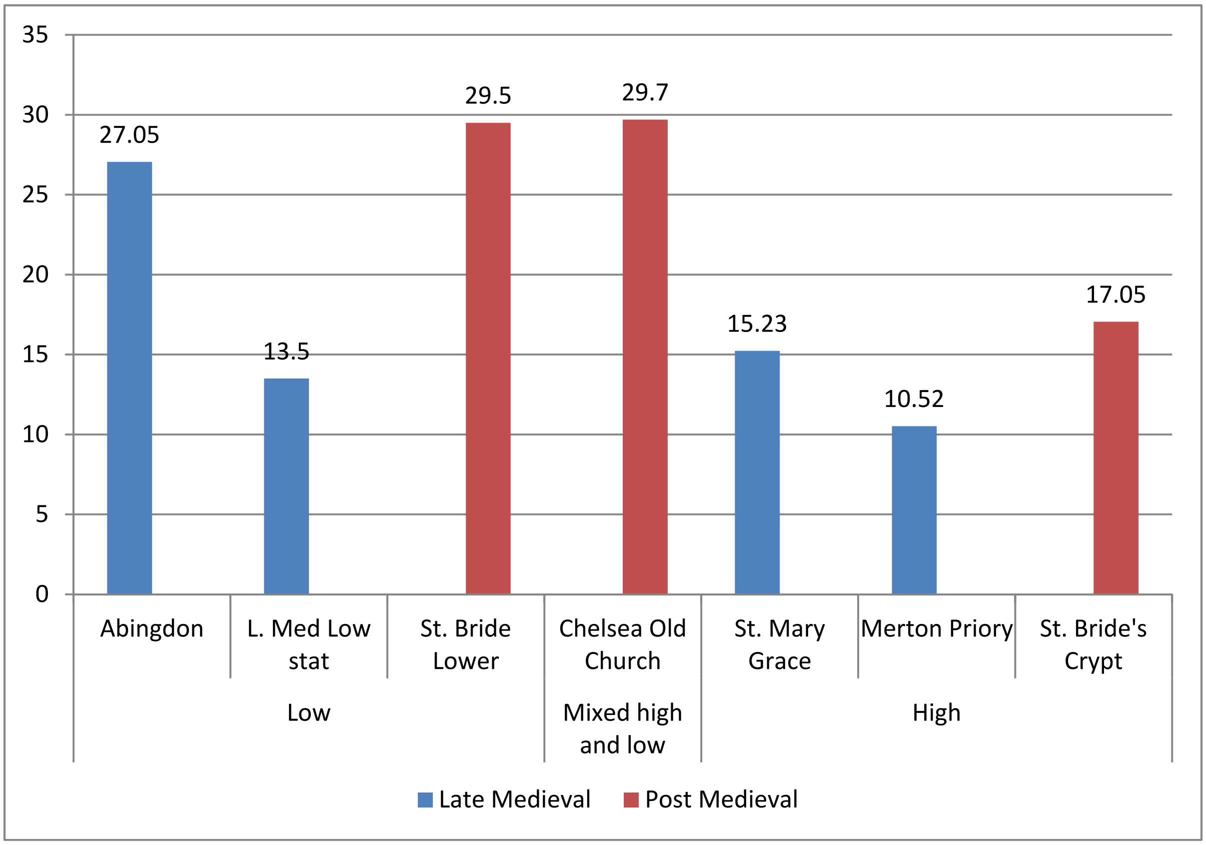


Figure 6.25: The TPR of individuals with of rib periostitis (individuals with rib periostitis on at least one rib as a percentage of the number of individuals with at least one rib preserved :social status

Additionally, unlike the prevalence rates for chronic maxillary sinusitis, even the Post Medieval populations do not follow the expected trend for status. Based on historical records, the highest concentrations of atmospheric pollution are expected in the industrial Post Medieval period (Brimblecombe 1987). It is therefore unsurprising that the low status population from St. Bride's Lower churchyard was one of the highest prevalence rates recorded for rib periostitis in this study and St. Bride's Crypt one of the lowest. However, the result from Chelsea Old church, which was a less urban and relatively higher status site, was almost identical to urban St. Bride's Lower. Given the more favourable semi-rural location, it is surprising that the prevalence rate for Chelsea Old Church was not significantly lower than the more urban St. Bride's parish. However, in addition to the high status individuals living in Chelsea, there were poorer individuals who were buried in this parish. According to Faulkner (1829: In Cowie *et al.* 2008) "there were poor in the parish, and in 1737 a workhouse was established in Chelsea for their employment" (Cowie *et al.* 2008). There was also archaeological evidence of small scale metalworking and gardening (Cowie *et al*. 2008). This could account for at least some of the cases of chronic maxillary sinusitis and rib periostitis, certainly in comparison to the high status population from St. Bride's Crypt, where the occupations were predominantly "white collar" (Scheuer and Black 1995). It also is possible that the population of Chelsea Old Church spent a lot of time in Central London, given its location and ease of access to the Thames River (Cowie *et al*. 2008).

However, the prevalence rate for chronic maxillary sinusitis for Chelsea Old Church fell midway between the two St. Bride's cemetery populations and was not equal to St. Bride's Lower, as it is here. This lack of correlation, again, suggests that the air quality is not responsible for both chronic maxillary sinusitis and rib periostitis in this population. Either the relatively lower prevalence of chronic maxillary sinusitis is expected because the population was exposed to less pollution than the lower status urban group, or the prevalence rate for rib periostitis is expected because the population was exposed to as much pollution as St. Bride's Lower as a result of occupation and general activity, or frequent trips into central London. It is not possible that both are true. Therefore, this suggests that air quality is either not responsible for causing chronic maxillary sinusitis, rib periostitis, or possibly both conditions. The only possible explanation that could account for both rib periostitis and chronic maxillary sinusitis being caused by air quality is if both environments had air containing very small particulates or chemicals that could reach the lungs and only the population from St. Bride's Lower was exposed to the type of air pollution that would cause chronic maxillary sinusitis. However, this is unlikely, given that particulates that are small enough to reach the lungs are small enough to reach and potentially affect the upper respiratory system.

There is also no more similarity for rib periostitis frequency within the groups of high status populations or the low status populations than within the group of Late Medieval and Post Medieval samples as a whole (see Figure 6.26). While Chelsea Old Church does not fit the expected pattern, the lower status St. Bride's Lower does have a significantly higher prevalence than high status St. Bride's Crypt. Like with chronic maxillary sinusitis, this could be a result of the different lifestyles exposing the populations to different amounts and types of pollution. Additionally as with chronic maxillary sinusitis, there is no significant difference between the high and low status urban populations in the Late Medieval Period, but there is a significant difference between Abingdon Vineyard, a lower status, at least partly rural population, and the other Late Medieval populations.

Abingdon Vineyard had the second highest prevalence rate for rib periostitis in this study, in spite of its rural location. It was significantly different from the other late medieval populations, with the exception of the next highest frequency, the combined sample made up of St. Nicholas Shambles and Guildhall Yard East. These two low status samples did have significantly different prevalence rates for chronic maxillary sinusitis. This is similar to the relatively high rate from semi-rural Chelsea Old Church. This could suggest that rural populations are more prone to developing inflammatory rib periostitis. However, this is not the case in any of the previous periods where the populations lived more or less universally in rural environments. With the exception of the Roman Period, all the prevalence rates were lower than either the Late or Post Medieval Periods. It is possible that there was a change in lifestyle for rural populations in the two latest periods, perhaps as a result of more intensive agriculture, which could be responsible for the high rates in rural populations (Dyer 2000). It is also possible that the rib periostitis in Abingdon and Chelsea were caused by something other than poor air quality. Merton Priory would have been located in a rural environment and the individuals buried in the cemetery mostly likely participated in some gardening. While this environment would have contained many of the same particulates as would be found around Abingdon, it is likely, given that they were personally performing much smaller scale horticultural activities, that they would have been exposed to lower concentrations of those pollutants. For example, the act of plowing or harvesting would likely expose the individual carrying out the act to much higher concentrations of dust, pollen, and fungi, more than individuals who were living nearby in the same environment but not carrying out this activity. However, there is also evidence of gardening in Chelsea, which had a significantly higher rate (Cowie *et al*. 2008). In addition, the population from Wharram Percy, a population that dates both earlier and later than Abingdon, examined by Lewis *et al.* (1995) had a significantly lower rate compared to Abingdon, despite also being rural. Again, this is not the expected pattern if poor air quality was a significant cause of rib periostitis.

This, however, does not rule out the possibility that air quality affected the population. The fuels that would have been used to heat and light their homes would have been similar between these populations, which could account for the overall similarities in rib lesion prevalence (Alcock 2006; Blair 2003; Brimblecombe 1987; Cunliffe 2004; Dyer 2000; Hamerow 2002; Perring 2002). However, if this is the case, then the assumption must be that the individuals who were buried in the crypt in St. Bride's Church, and who lived in the Iron Age and Early Medieval Periods, lived in an environment where either cleaner fuels were used, or where they were used differently resulting in less harmful gases and particulates being released, resulting in a lower prevalence rate for rib periostitis, and in the case of the latter two periods, there is no evidence of this. It is possible that the buildings in the Iron Age and Early Medieval Periods were better ventilated than the other periods discussed here. However, this would, once again, not explain the high rates of chronic maxillary sinusitis, if in fact both are caused by poor air quality.

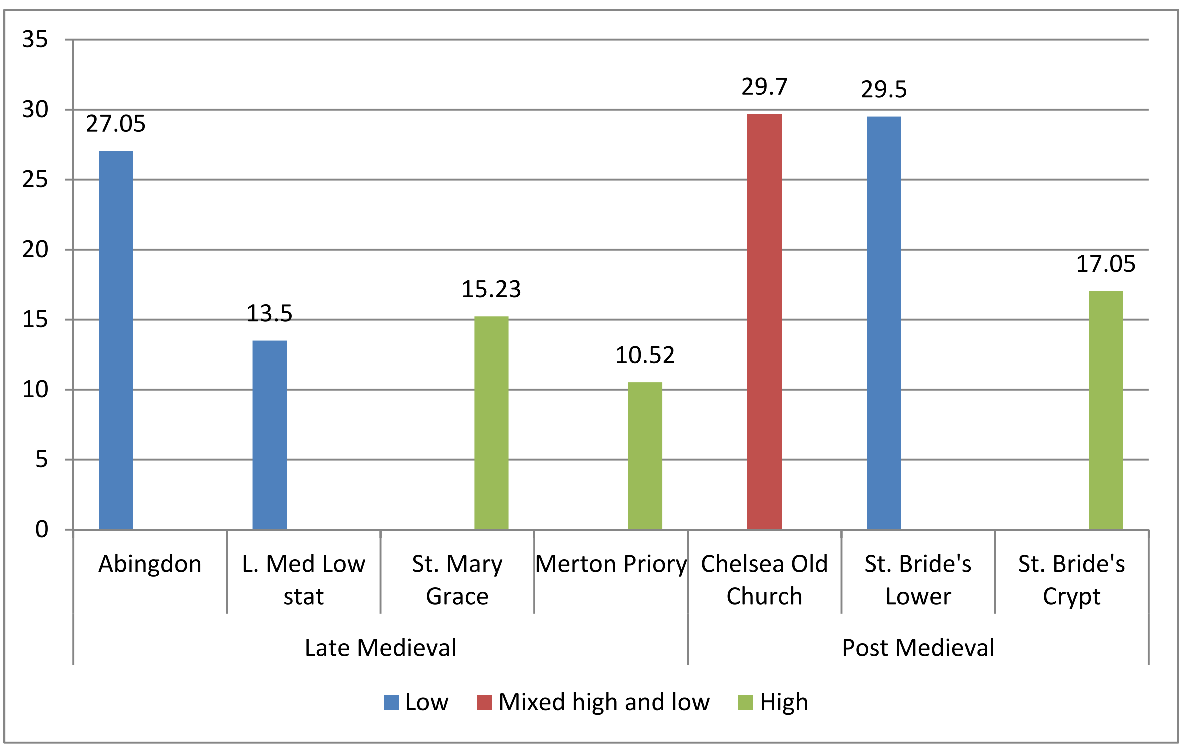


Figure 6.26: The prevalence of individuals with rib periostitis (individuals with rib periostitis on at least one rib as a percentage of the number of individuals with at least one rib preserved), arranged chronologically: low, mixed high/low, and high social status

Unlike in any of the previous periods there is one more factor that needs to be taken into consideration for the Post Medieval Period. It was during this period that smoking tobacco came into fashion. Smoking is the most common cause of respiratory disease in living populations (World Health Organisation 2006). Given this, it would be expected to increase the prevalence of lower respiratory disease in particular in the Post Medieval populations where smoking was common (Cowie 2008; Kausmally 2008; Walker and Henderson 2010). Pipes were used to smoke tobacco and might be held in the mouth, between the teeth for long periods of time, and in some individuals, who smoked habitually, this may have worn the teeth down so significantly that it left a visible facet in their teeth (see Figure 6.27). It may also leave a staining on the teeth, which can survive burial (Walker and Henderson 2010).

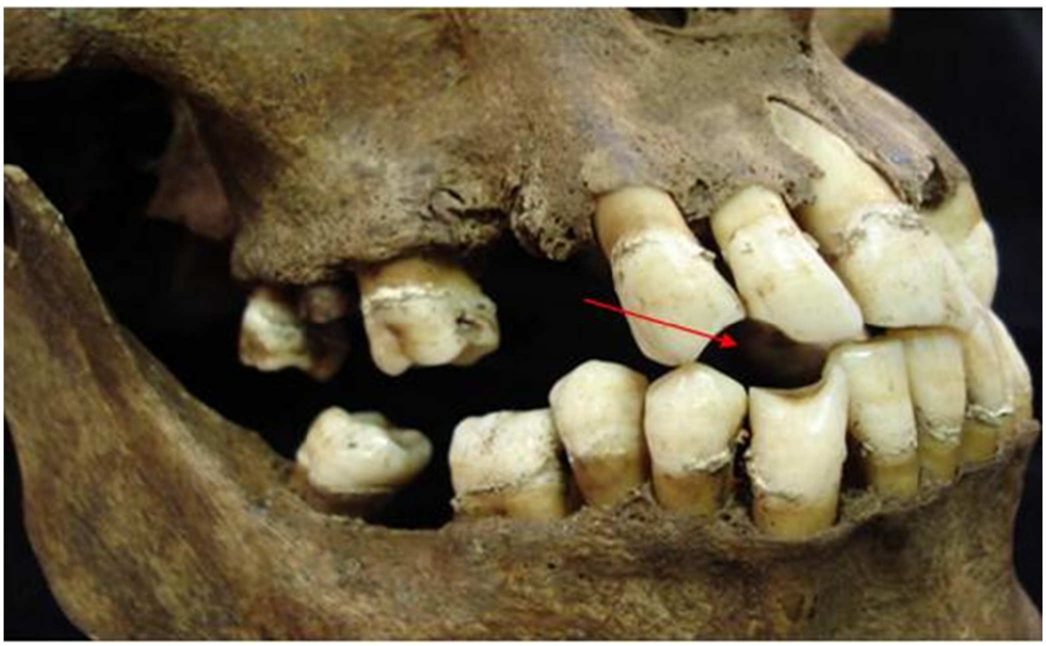


Figure 6.27: Pipe Facet, Image of individual from post-medieval St. Benet Sherehog, London (from The Wellcome Osteological Research Database http://www.museumoflondon.org.uk/English/Collections/OnlineResources/CHB/Resources/Photographs/lowerstbrides1.htm)

During an examination of the cemetery from the Catholic Mission of St Mary and St Michael in the Whitechapel area of London, dated to 1843-1854, Walker and Henderson (2010) found that 58 individuals with pipe facets, in addition to brown staining on the lingual side of the teeth, were significantly more likely to have visceral rib periostitis than those without. The CPR was nearly twice as high amongst individuals who had evidence of pipe smoking. This follows the pattern seen in living populations. However, 10 individuals from St. Bride's Lower examined in this study, were previously recorded by Kausmally (The Wellcome Osteological Research Database [WORD], 2009) as having pipe facets. These 10 individuals had a lower, although not significantly lower, TPR for rib periostitis compared to the rest of the population. This is unexpected given that smoking is so well correlated with lower respiratory disease in living populations. It is possible that these individuals died before they developed lesions on their ribs, but given that they held a pipe in their mouth long enough to develop noticeable facets, this seems unlikely. It is possible that these 10 individuals were too small a sample and the results are not meaningful. As pipe facets were not recorded for Chelsea Old Church, it cannot be said at the moment whether there were more, less, or the same number of individuals who smoked in this population, which might explain the similarity to St. Bride's Lower in spite of different environments. Conversely, as pipe facets were not recorded in this study, there is no evidence that the population buried in St. Bride's Crypt smoked less than the other two Post Medieval populations who had higher prevalence rates for rib periostitis. Given that pipe facets require very long periods of consistently holding a pipe in the location on the jaw there may be many individuals who smoked frequently who never developed visible pipe facets. Furthermore, while both high and low status individuals may have smoked tobacco, not all of these groups used pipes. Some individuals from higher status groups may have used snuff or cigars (Mitchell 1996). This could potentially confound the results. However, this certainly should be examined further using TPRs in other post medieval populations.

Unfortunately, it is impossible to determine the effect of exposure to poor air quality through directly linking this to occupation using the samples that have been analysed in this study. While there were occupations that could be associated with some of the named individuals from St. Bride's Crypt and Chelsea Old Church, these individuals made up a very small sample, and none of the occupations from St. Bride's Church would have been associated with poor air quality, as might be expected, given the overall high status of the populations interred there (Scheuer and Black 1995).

Amongst the sample not divided into urban and rural, or high and low status, groups, the expected pattern is still not seen. The prevalence rates for rib periostitis in the Iron Age and Early Medieval Periods were the lowest recorded in this study, while the rates for the Roman Period were more similar to the Late Medieval and Post Medieval populations. Roman

London was higher than Lankhills, but not significantly, which seems to indicate that being in the relatively more urban, although still largely rural, environment played no role in the development of rib periostitis. Given that London, at this time, would not have been urban in the modern sense, but more like a town, the low population density might have meant the environment was less polluted and more similar to the rural populations. It is not entirely certain that these people buried in the cemeteries associated with the town lived their lives in the town. It is possible that having lived elsewhere they were buried in the cemeteries outside the city walls either due to immigration or political reasons (Barber and Bowsher 2000).

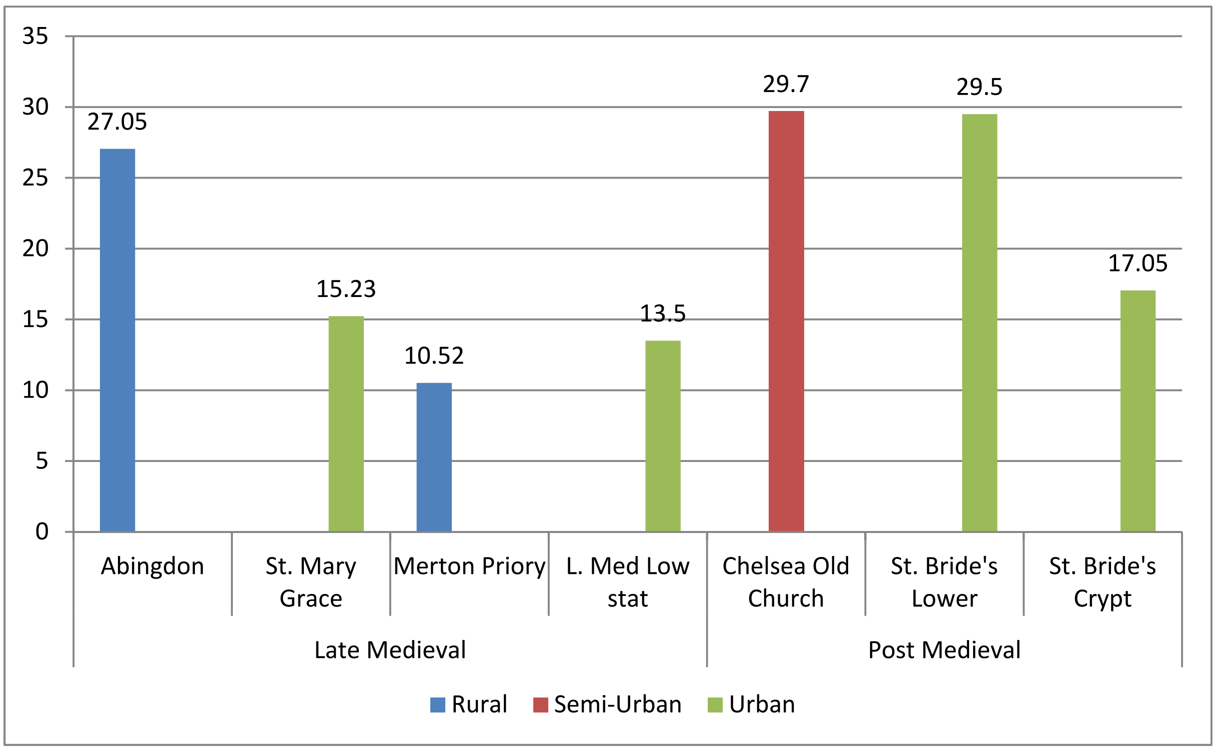


Figure 6.28: TPR for individuals with rib periostitis (individuals with rib periostitis on at least one rib as a percentage of the number of individuals with at least one rib preserved), divided chronologically for comparison of rural and urban environments

These results are also in contrast to the low rates for rib periostitis seen in both the Iron Age and Early Medieval populations. The TPR for the Iron Age was the lowest recorded in this study, with the two Early Medieval populations having slightly, but not significantly, higher rates. It is possible that the low rates could be explained by the low population density and rural environment in which people lived in these two periods, but the environment in Roman towns would not have been so significantly more polluted than a significantly higher rate of rib periostitis would be expected (Barber and Bowsher 2000). In spite of the similarity of environment, Roman London had significantly higher rates than both the Iron Age and Early Medieval populations, and Lankhills was significantly higher than the Iron Age populations.

The low prevalence of rib periostitis in the Roman period is in stark contrast to the high prevalence of chronic maxillary sinusitis. Hypothetically, it is possible that within the home, the particulates that were in high enough concentrations to cause more than 75% to develop chronic maxillary sinusitis (assuming that this is the predominant cause), were large enough to be inhaled into the upper airway, but too large to reach the lungs where they could lead to lower respiratory disease. This could also be the case in the Early Medieval Period. It is possible that the changes in lifestyle that caused the prevalence of rib periostitis to decline in the Early Medieval Period are also responsible for the increase in chronic maxillary sinusitis. If the pollutants found in this period were larger, they would have had little effect on the lungs compared to the sinuses. This is more likely than the alternative scenario occurring in Post Medieval Chelsea, although this is still just speculation. However, if we assume smoke was among the most common causes of air pollution, this would not be the case (Boman *et al.* 2006; Collings *et al.* 1990; Schwela 1997). All the populations would have been exposed to roughly the same particulates if they were coming from the same source (fire). If, however, they included larger particulates such as animal dander or dust in one environment but not another, this could potentially explain the differences between two seemingly similar populations. However, it does not explain why the rates of rib periostitis in the Roman Period were relatively high while chronic maxillary sinusitis was relatively low. This once again suggests that either only one type of the two lesions discussed in this study, or possibly neither, is caused by poor air quality.

6.5 Chronic maxillary sinusitis and dental disease

Dental disease has been cited as a frequent cause of chronic maxillary sinusitis in the clinical literature as discussed in Chapter 2 (Brook 2006; Charfi *et al*. 2007; Legert *et al*. 2004; Mehra and Jeong 2009; Racic *et al*. 2004; Ugincius *et al*. 2006). Given the rates in living populations, it is likely that dental disease is responsible for a significant proportion of the chronic maxillary sinusitis in all the populations examined here and previously examined by other researchers. The question is whether dental disease is primarily responsible for the prevalence of chronic maxillary sinusitis in any or all of the populations examined in this study.

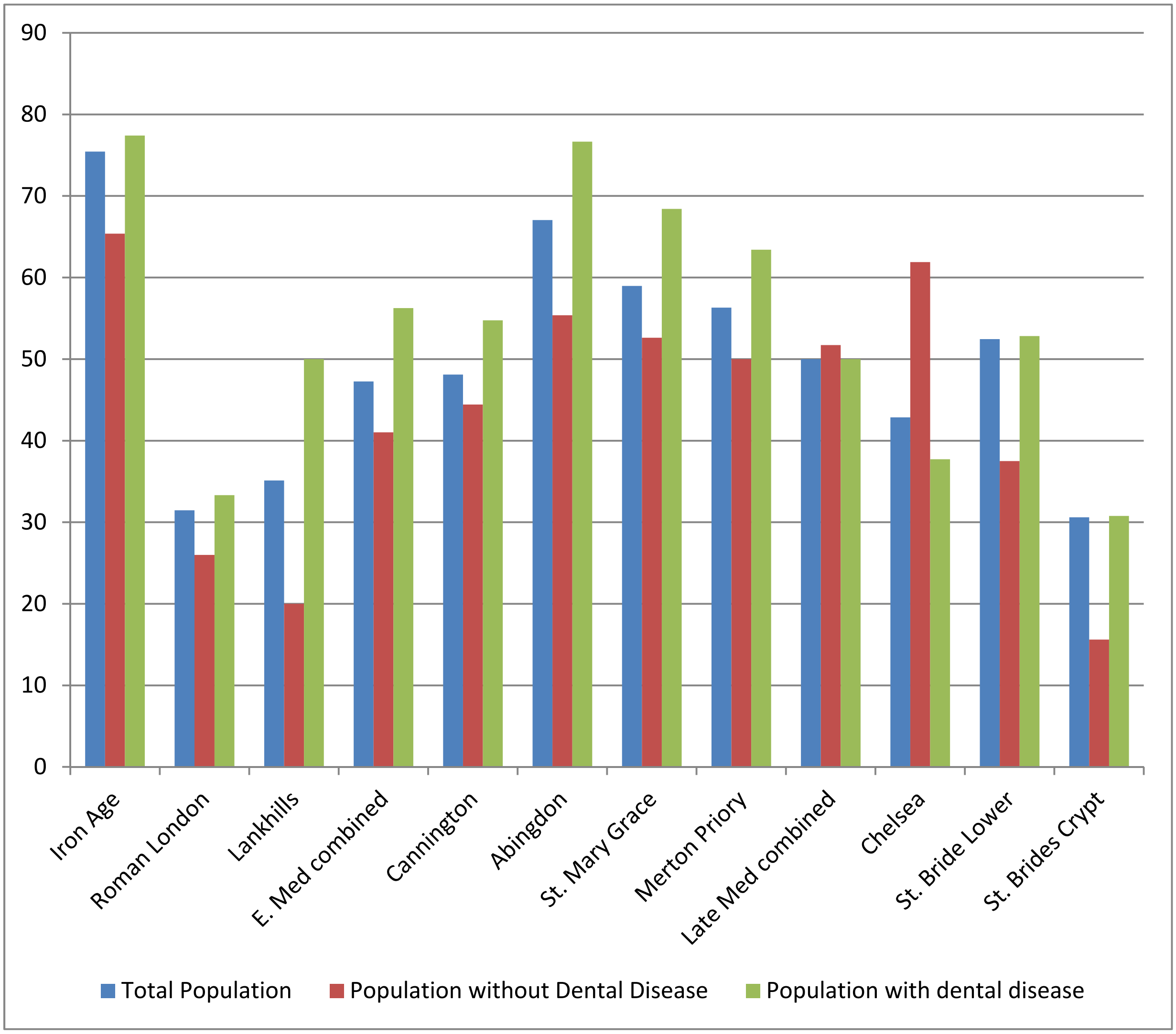


Figure 6.29: Comparison of the prevalence of chronic maxillary sinusitis calculated per individual, comparing the total population to the sub samples only made up of individuals with no dental disease and with dental disease

In order to determine whether this is the case, any individuals who had dental disease that directly affected the maxilla, in particular abscesses and ante-mortem tooth loss, were removed from the sample and a new prevalence rate calculated. Using the entire sample of 1203 individuals examined during this study, chi-squared tests and odds ratios were used to determine the likelihood of an individual having both chronic maxillary sinusitis and these forms of dental disease to determine whether there was an effect. Abscesses in the posterior maxillary teeth, which can create a sinus directly into the maxillary sinus, are the most likely to be associated with chronic maxillary sinusitis. Abscesses that result in a sinus in other parts of the maxilla, typically medially or laterally, were also significantly more likely to be associated with chronic maxillary sinusitis. While this does not directly affect the sinus, it is possible that the remodelling of the maxilla as a result of the infection, or the movement of bacteria from the dental abscess into the sinuses causes an osteological reaction within the maxillary sinus. Ante-mortem tooth loss was also significantly more likely to be found associated with chronic maxillary sinusitis than would be expected if this were random. Again, either the dental disease that caused the tooth loss, or the remodelling of the maxilla, once the tooth is lost, could cause the inner surface of the maxillary sinus to remodel as well.

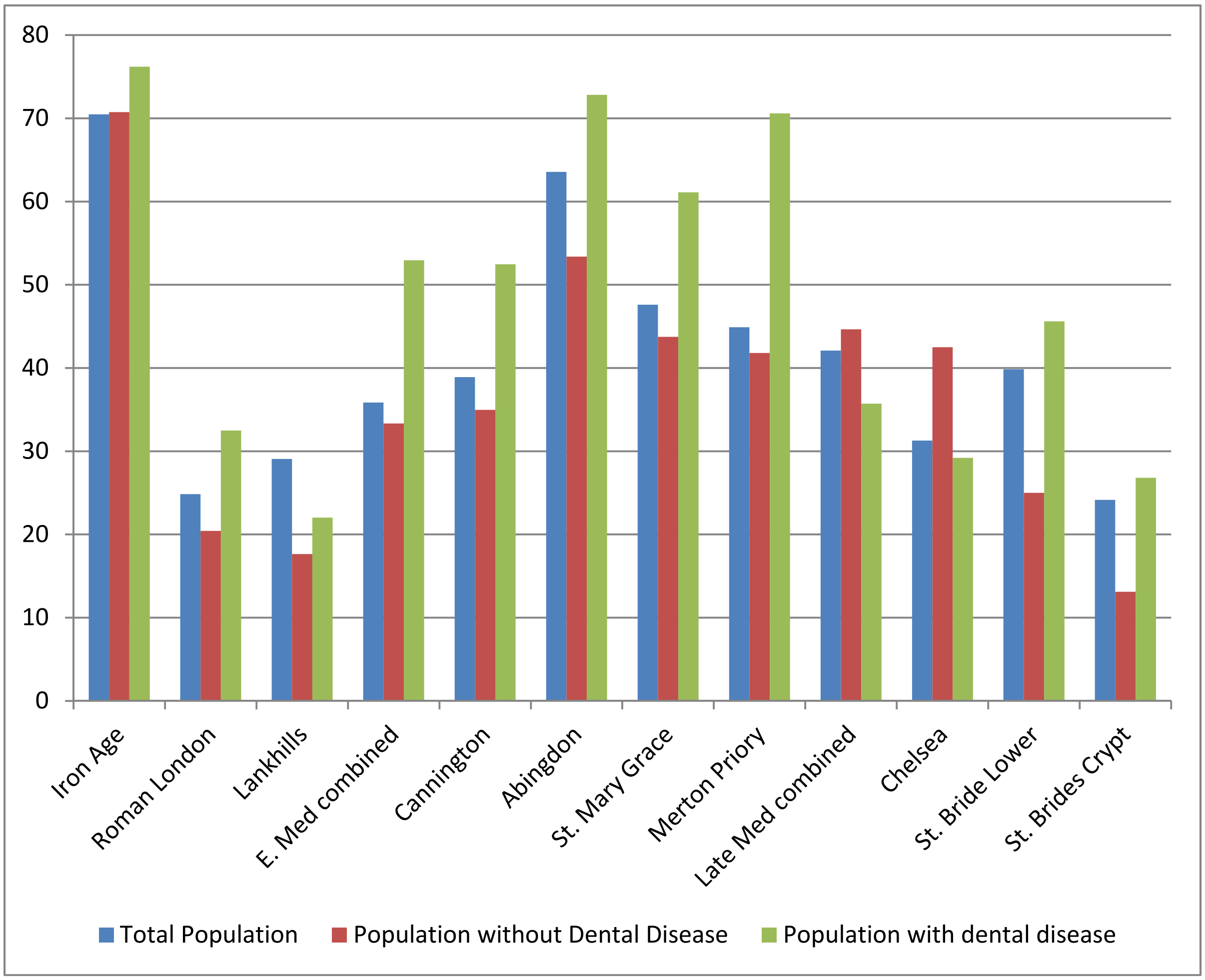


Figure 6.30: The prevalence of chronic maxillary sinusitis calculated per sinus, comparing the total sample to the sample made up of only individuals not containing any dental disease and the sample containing dental disease

As discussed in the Section 6.2, in none of the twelve populations was the difference between the prevalence in the population as a whole significantly different from the population when individuals with maxillary abscesses or ante-mortem tooth loss are removed.

There were also no significant differences between the prevalence in the population not including dental disease and only the individuals with dental disease. This would appear to be strong evidence against these dental conditions all being responsible for chronic maxillary sinusitis. However, individually, each of these forms of dental disease are significantly more likely to be found in combination with chronic maxillary sinusitis than without, which would suggest some correlation. Even when calculated per sinus, the results were not significant. These two methods of analysis of the data provided contradictory results. It appears that, although the three types of dental disease were significantly more likely to be found with chronic maxillary sinusitis, in no instance did this result in a significantly higher prevalence of chronic maxillary sinusitis in samples with dental disease. However, 51.3% of the sinuses with chronic maxillary sinusitis in the total sample had visible dental disease. If only visible dental disease is potentially causing chronic maxillary sinusitis, then something else is causing chronic maxillary sinusitis in the other half of the population. Figures 6.29 and 6.30 graphically represent the relative prevalence rates of chronic maxillary sinusitis in the total sample and subsamples with and without dental disease.

6.6 Respiratory disease and climate

The advantage of a study that covers this lengthy period of time is that it is capable of examining a small range of climate change in the same environment in order to determine whether this has any effect on the prevalence of these lesions in skeletal remains. As previously discussed in Section 3.4, studies of climate in the past have relied on a number of sources of evidence. In the earlier periods examined in this study, where historical documentation of climate and other related activities which rely heavily on climate, such as agriculture, are unavailable, but indirect measures of average temperature and rainfall can be used. These methods include analysis of tree rings, and climate sensitive floral and faunal remains, which change in number and location as the climate changes in a given region. On a larger scale, analysis of ice cores in the arctic can be used to assess the climate throughout human history (Barker *et al*. 2004; Cole and Marsh 2006; Coope *et al*. 1997; Dennis and Sparks 2007; Dunca *et al*. 2005; Hopcroft *et al*. 2007; Jones and Briffa 2006; Lageard *et al*. 1999; Langdon *et al*. 2004; Macklin and Rumsby 2007; Slonosky *et al*. 2001).

In later periods, where historical documents are available, finer detail of climate can be determined (Slonosky *et al*. 2001), although these may be biased by the intent of the author.

For example, their interpretation of an environment will be heavily influenced by the environments they have previously been in. It is also possible that this bias was intentional if the purpose of the document was to alter opinions. For example, some writers may have exaggerated the extent of air pollution in order to influence laws that limit industrial activity. Even before climate conditions themselves were recorded, in the Post Medieval Period, records of other activities can be used as indirect evidence of climate. For example, records of harvests on estates, the amount of extra staff hired and the times they were hired can provide evidence of the success and timing of the harvest and, indirectly, the climate conditions during that year, including how wet or dry it was, depending on the species of crop. The difficulty with this is, no matter how detailed our knowledge of climate in the past, our knowledge of the exact time an individual lived, absent information such as coffin plates, is limited. If we know that particular years were cold or wet, when examining a cemetery that was in use for hundreds of years, we cannot know who or how many of the individuals buried there were living at that time.

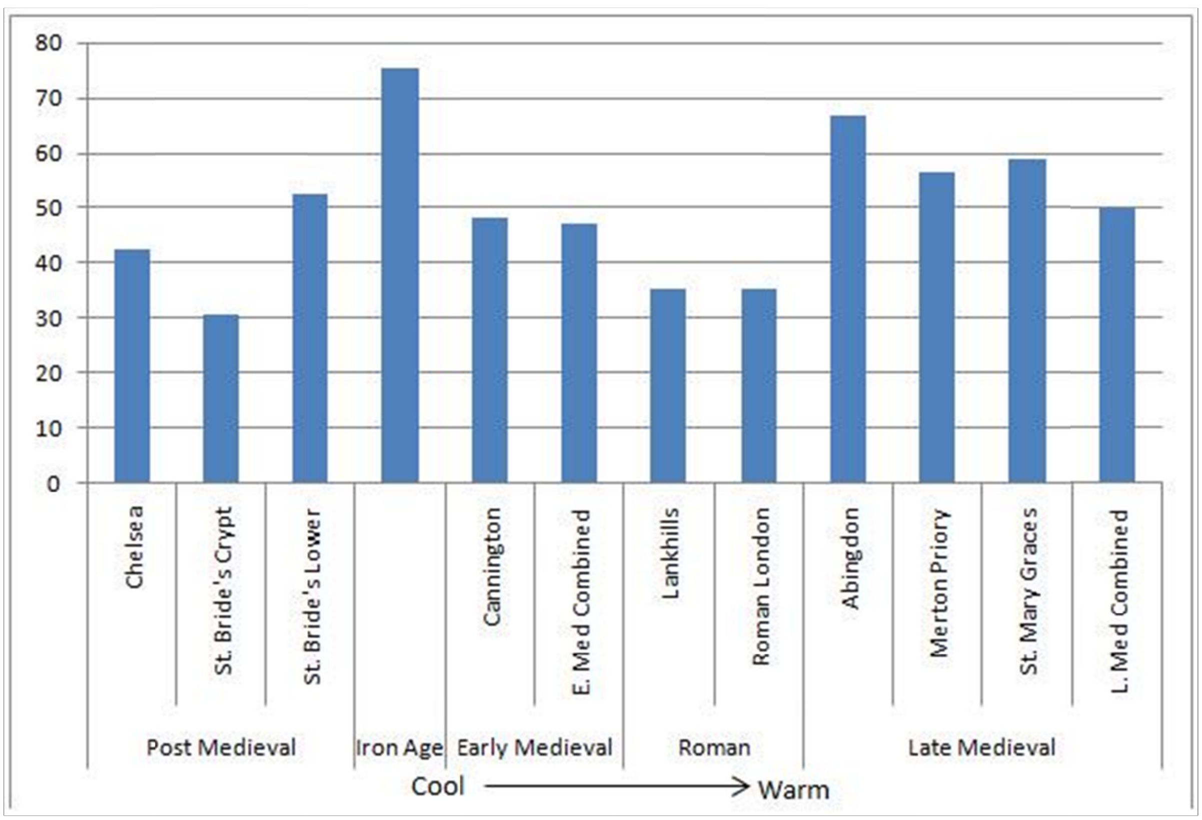


Figure 6.31: The TPR of individuals with chronic maxillary sinusitis, arranged by average temperature from cooler (on left) to warmer (on right)

The recent concern over global warming has led to many large scale projects examining climate within past millennia in order to place changes in our current climate in context. These studies have correlated several types of evidence to reconstruct climate and filled in any gaps using statistics and modelling. Using the results of these studies (see Section 5.3), Figure 6.31, shows the prevalence of chronic maxillary sinusitis in each of the populations when the periods are arranged from the lowest average temperature to the highest average temperature for the period. Within the periods, the urban sites are placed at the "warm" end as urban sites tend to be slightly warmer due to the inherent heat produced by so many people so close together and the lack of wind, which is arrested/changed by the buildings (Brimblecombe 1987). Even when dental disease is removed (see Figure 6.32) as a possible confounding factor, there is no evidence of a correlation between the average temperature over these periods and the prevalence of chronic maxillary sinusitis.

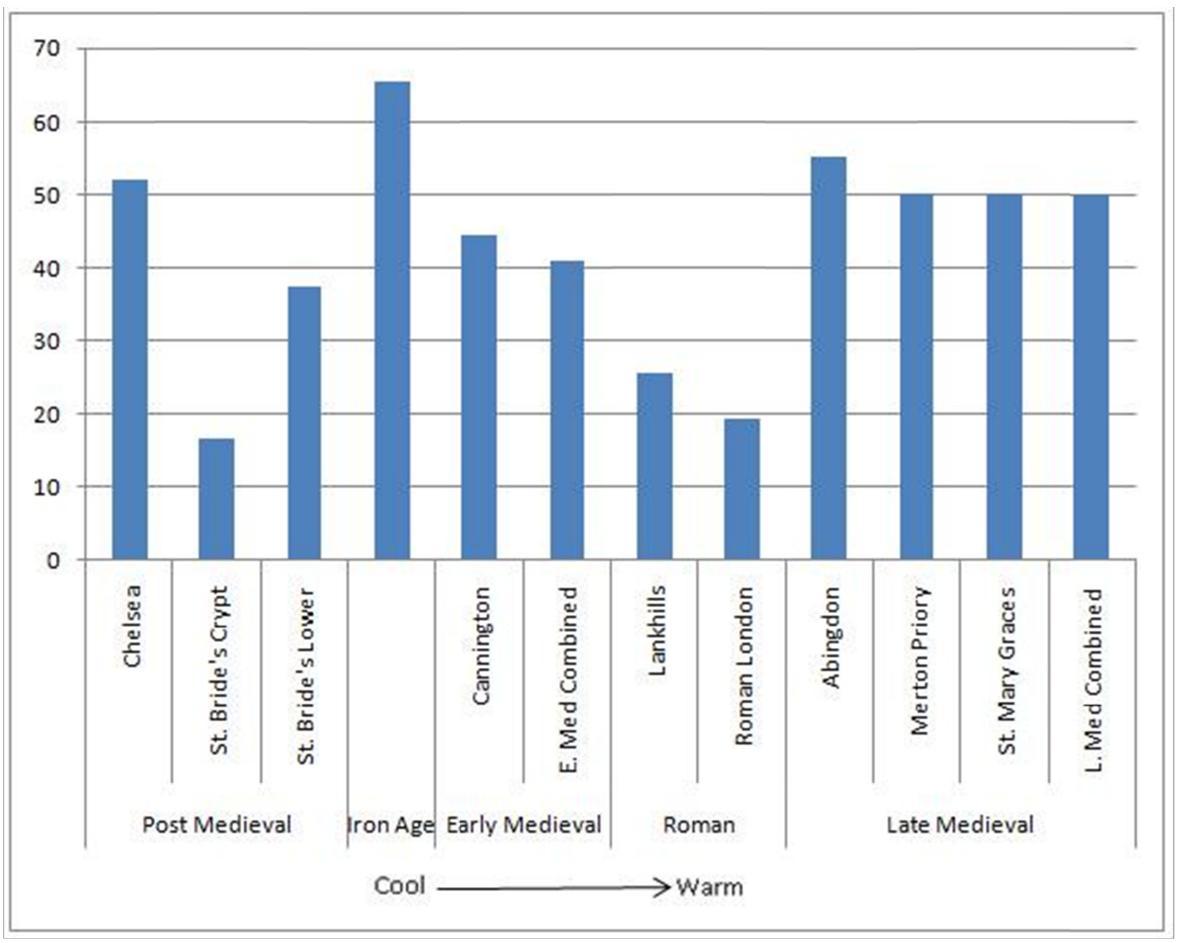


Figure 6.32: The TPR of individuals with chronic maxillary sinusitis after removing all individuals with dental disease from the sample, arranged by average temperature from cooler (on left) to warmer (on right)

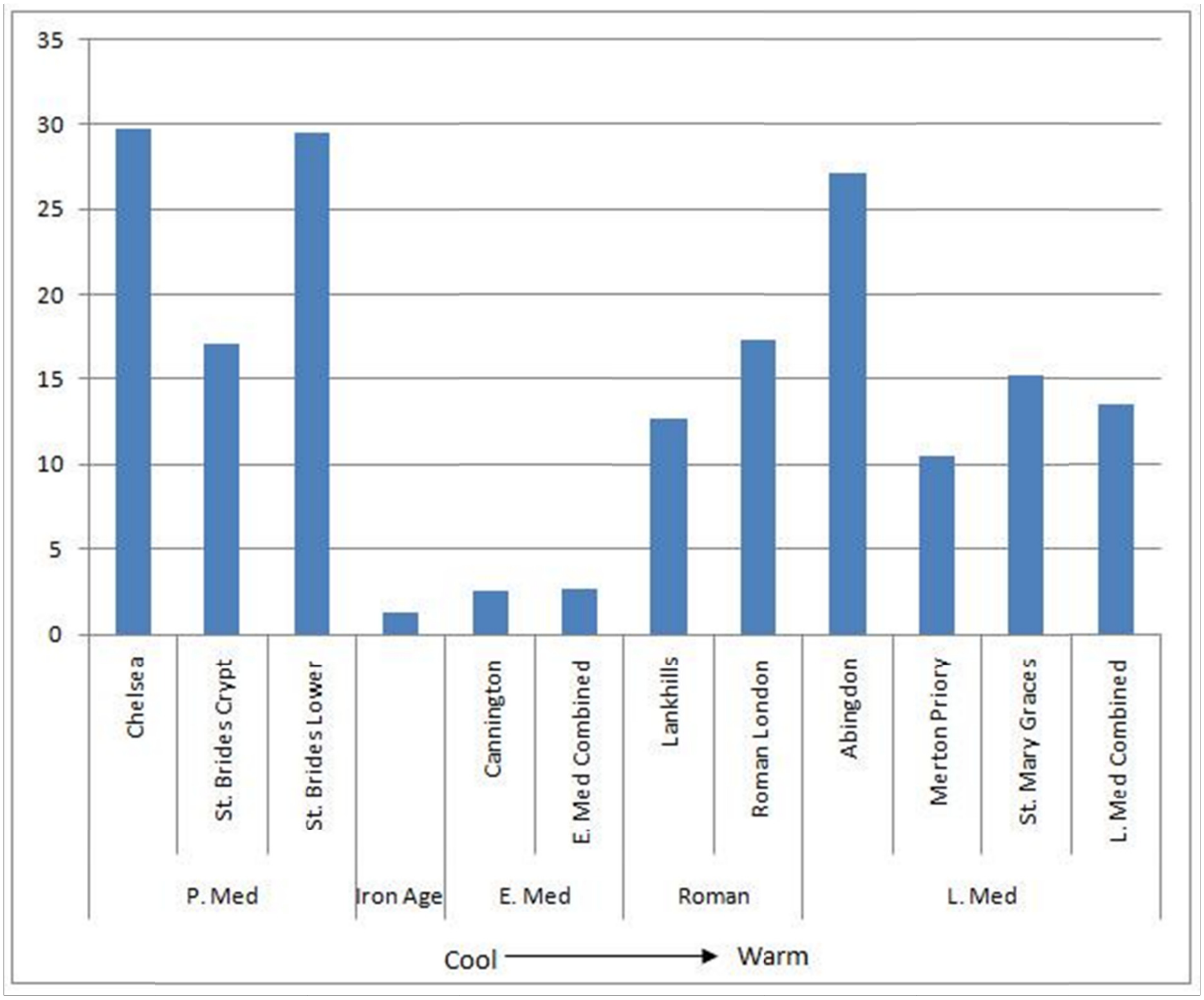


Figure 6.33: The TPR of rib periostitis, calculated per individual, arranged by average temperature, from cooler (left) to warmer (right)

In Figure 6.33, it is clear that rib periostitis also does not correlate with the average temperature. Unfortunately, these types of correlations are problematic because these periods range over hundreds of years and the temperature would not have remained consistent throughout. The average rainfall and humidity also needs to be taken into account, which would affect respiratory health directly and indirectly through pollen in the air from vegetation as well as determining time spent indoors and whether the indoor spaces are heated. However, these variables are impossible to determine before accurate records were kept by the contemporaneous populations. It is possible that short term climate changes affected the individuals in the cemetery population who were alive at the time. It may even be possible to determine these when these short term changes occur, based on historical records as described above. However, it would be impossible to know which of the individuals buried in a cemetery used over several generations were living during a specific year while the climate was particularly cool or warm, or wet or dry.

It is equally possible that the relatively small range of climate change that is seen in this region, in the last millennium, is not large enough to produce a significant effect on respiratory health. Therefore, these results need to be compared with prevalence rates from populations who lived in significantly different climates, such as the Aleutian Islanders, for the most part from what is now Alaska (16th C) who would have experienced colder conditions at some points during the year, and the population from 6th to 8th century Kulubnarti, Sudan who would have been exposed to relatively warm and dry conditions (Roberts 2007) (see Figure 6.15). Although the prevalence rate for Kulubnarti (21.8%) is significantly lower than most, but not all, of the populations examined in this study, the prevalence rate for the Aleutian Islanders (42.9%) is well within the range for the populations examined in this study.

Unfortunately, even in the case of Kulubnarti, if there had been significant differences in rates with the Aleutian Islanders, or any other population in a different environment, the significant differences in lifestyle could be equally responsible for any differences between these populations. With so many confounding factors, it is still difficult to determine the extent of the effect of climate, if any, on the development of chronic maxillary sinusitis and lower respiratory infection in this study. There appears to be a relationship between respiratory complaints and cold temperatures in living populations, but it is unclear what the exact reason for this increase is. It could be related to the changes in lifestyle that occur when the weather is colder, such as more time spent indoors (Hajat and Haines 2002).

While this does not eliminate the possibility that climate affects the prevalence of chronic maxillary sinusitis or rib periostitis, it is clear from the lack of correlation that average temperature, at least, is not the only factor affecting the presence of these conditions, or certainly does not have enough impact to be seen on skeletal remains. In the future, a more thorough look at effects of climate, including factors such as rainfall and types and quantity of vegetation, might produce clearer results.

6.7 Respiratory disease and infection

Both lesions that were examined in this study are commonly caused by inflammation in the nearby soft tissue. This inflammation can result from infection as well as the irritation associated with air pollution. The infection can either be localised to the sinuses or the lungs or could be a result of systemic infectious diseases that affect many organs, such as tuberculosis and leprosy. Given the relatively high prevalence of rib periostitis in the Roman period as well as in the Late and Post Medieval periods, where the population densities were relatively higher, infection is a likely cause. Much of the research into the relationship between the rib periostitis and infection has concerned tuberculosis, as discussed in Chapter 2, with mixed results. However, Boocock *et al.* (1995) examined the link between chronic maxillary sinusitis and leprosy in the population from the late medieval hospital in Chichester (Magilton *et al*. 2008). The individuals with skeletal evidence of leprosy did not have a significantly higher prevalence rate than the population as a whole. Unfortunately, as there may have been many individuals in the cemetery who suffered from leprosy or other infectious disease, who did not have the characteristic skeletal lesions, this does not exclude the possibility that chronic maxillary sinusitis was more common in individuals with leprosy.

The literature recently has examined the association of rib periostitis with tuberculosis (Kelley and Micozzi 1984; Matos and Santos 2006; Mays *et al.* 2002; Roberts *et al.* 1998a; Santos and Roberts 2006). While studies which have attempted to link these lesions with the disease have had varying outcomes, it is possible that some of the lesions seen in these populations are caused by tuberculosis. In the individuals where rib periostitis was present, the remainder of the skeleton was examined for other indicators of tuberculosis. However, in no cases were there lesions characteristic of TB found.

In spite of the extensive amount of information in the clinical literature, localised infection, infection limited to the maxillary sinuses or the lungs and pleura, has been largely ignored as a possible cause of these lesions. Unfortunately, localised infection can only be characterised by a lack of lesions anywhere else in the skeleton, making differential diagnosis difficult to prove. However, it is likely that infection would be localised to the respiratory system, without having an effect on the remainder of the skeleton and that this inflammation might persist over a long period of time or as a result of frequent reoccurrence.

The difficulty with this hypothesis is that infections are unlikely to affect a large proportion of the population and many of the populations in this study had prevalence rates of chronic maxillary sinusitis over 50%. Given that the prevalence rates would not include acute infections that did not cause lesions, the calculated prevalence rate would actually be representative of a much higher real prevalence. Slightly less implausible, the highest prevalence of rib periostitis was in the Post Medieval period at just below 30%. This seems fairly high, given that the condition would have to be persistent in order to cause bone remodelling and it is likely that the individuals with lesions represent a much higher prevalence, which would have included individuals who recovered quickly or died before the skeleton could remodel.

As the individuals recovered from St. Bride's Crypt were named, some of these individuals could be associated with a recorded cause of death and possibly even other lifestyle and health information. There were three individuals at St. Bride's for whom the cause of death on record was related to respiratory disease recorded during the initial analysis of the remains by Scheuer and Black (1995). One male in the old age category had the cause of death listed as pleurisy. Another man, in the same age category, had listed under cause of death, "disease of the chest". One female in the old age category was listed as having asthma. None of these three individuals had any evidence of lesions on their ribs or in their sinuses. It is possible that this is due to the osteological paradox (Wood *et al* 1992). For the most part, the chronic inflammation of the tissue in the sinuses that can result in lesions on the ribs, as a result of being chronic, would not in itself be a cause of death. In instances of acute respiratory disease that is fatal, the disease would not have persisted for long enough to result in skeletal lesions. As mentioned above, this also makes it difficult to attribute all of the visible cases of chronic maxillary sinusitis to infection or infectious disease, as these are unlikely to be visible in upwards of 50% of the population, let alone the 75% prevalence seen in the Iron Age sample analysed in this study. It is probable that infection contributes to the prevalence rates for both lesions, perhaps even a significant amount but, given the high prevalence, it is likely that there are other factors operating.

6.8 Respiratory disease and allergens

6.8.1 Evidence for localised inflammation as a cause of lesions in the maxillary sinus

More and more research in the clinical literature concerning chronic maxillary sinusitis has explored localised inflammation and in particular the role of the immune system in the development of chronic maxillary sinusitis. While inflammation can be caused by a localised infection, as discussed in Section 6.8, host factors can also cause localised inflammation. As discussed in Section 2.1.2, some individuals may be predisposed to have immune reactions without sufficient cause, as in the case of allergies. This can lead to remodelling in the sinuses without any apparent environmental cause (Krouse 2005; Ramanathan and Lane 2007; Steinke and Borish 2004).

Unfortunately, localised inflammation, whatever the cause, is difficult to prove in skeletal remains. Unlike systemic diseases like tuberculosis or leprosy, localised infection would leave no other traces in the skeleton. It is likely that environmental factors, such as air quality, that affect both sinuses to a roughly equal extent will be as likely to cause inflammation in either of the sinuses and it seems likely that this would lead to bilateral presentation. Other factors that will affect one side of the maxilla more, such as dental disease in the posterior maxillary teeth on only one side of the mouth, might be expected to present unilateral chronic maxillary sinusitis. In the case of localised infection, it is possible for only one sinus to become infected and inflamed if the cause of the immune reaction is only on one side. In this study 42.67% of the individuals with chronic maxillary sinusitis, with both sinuses preserved, had unilateral chronic maxillary sinusitis compared to 57.32% individuals who had remodelling in both sinuses. This could be accounted for by dental disease, which may affect one side, but when individuals with dental disease, either directly affecting the sinus through a drainage sinus, or indirectly affecting the sinus by causing remodelling of the posterior part of the maxilla, are removed from the sample, 18.5% of the cases of chronic maxillary sinusitis are still unilateral. In instances where the only remaining evidence of a condition is remodelling within the maxillary sinus, the lack of other lesions is the only possible diagnostic criteria.

6.8.2 Allergies

There are other factors that could increase the likelihood of an allergic reaction. Inhalation of bacteria, viruses, fungi or other particulates are more likely to occur where they are common in the air. Therefore, environments with higher concentrations of particulates, such as pollen or dust, caused by changes in climate or deforestation might indirectly result in more cases of chronic maxillary sinusitis as a result of allergic reactions (Trevino 1996). Similarly, living in environments with poor ventilation leading to high concentrations of particulates, including smoke and animal dander, would put individuals at increased risk (Trevino 1996). It also seems more likely that individuals suddenly exposed to a new substance, either due to climate change, or migration to a new environment, are more likely to react to a foreign substance in spite of it being harmless (Maksimovic *et al*. 2010; Steinke and Borish 2004).

There is some evidence that allergies may be hereditary and, in that case, it may be expected that chronic maxillary sinusitis would be more predominant in individual families (Maksimovic *et al*. 2010). Unfortunately, it is impossible to identify families from all but one site. Since the individuals from St. Bride's Crypt were named it would be possible to determine, at least in the male lines where names do not change with marriage, who was related to whom. However, these multi-generational families are relatively rare in the crypt, which was in use for a relatively short time, and not all these individuals had sinuses preserved to be examined in this study. As such, they make up too small a proportion to present any meaningful result. However, in the future, if there are other populations with familial relationships, it would be interesting to test this theory.

6.9 Summary

While there are few solid conclusions to be drawn from the results of this study, this in itself is an important conclusion. The lesions found on the inside of the maxillary sinus and the visceral surface of the ribs have occasionally been attributed to possible causes that have then been accepted by other researchers and used to make inferences about health and environment. However, it is clear that the causes of these lesions are complex and require a great deal more research before they can be used with any confidence as indicators of lifestyle, health, or environment. These results suggest that air quality is certainly not the only cause of chronic maxillary sinusitis or rib periostitis, if it has any significant effect at all. It is possible that exposure to certain types of pollutants caused by lifestyle are responsible for chronic maxillary sinusitis or rib periostitis. This would need to be examined further using populations with known histories before it could be accepted or ruled out entirely. In addition to air quality, dental disease and localised inflammation caused by infection or allergies should be considered in future work. It is important to understand that the causes of chronic maxillary sinusitis are numerous and it is unlikely that one cause is responsible for all of the maxillary sinus bone remodelling seen in the archaeological record. Given this, researchers must be cautious when assigning any cause to these lesions. Furthermore, until the causes of chronic maxillary sinusitis can be determined with more certainty, lesions in the maxillary sinus should not be used as evidence of lifestyle, environment, or pathogen load, but rather confirmed using evidence of these factors from other skeletal lesions and other parts of the archaeological record.

7 Conclusion

The data collected and analysed in this study did not support the hypothesis proposed, that populations believed to have been exposed to higher concentrations of poor air quality would have higher prevalence rates for chronic maxillary sinusitis and rib periostitis. Previous smaller scale studies have found that some urban and/or low status populations had higher prevalence rates of chronic maxillary sinusitis than their higher status or rural counterparts (Lewis *et al.* 1995; Roberts 2007). However, as has been seen in Chapter 2, this was not consistently the case when comparing all the populations previously examined. This study also found no direct correlation between relative air pollution either inside or outside the home environment and the prevalence of chronic maxillary sinusitis or rib periostitis. The samples from urban environments did not consistently have higher prevalence rates for chronic maxillary sinusitis or rib periostitis. Samples that were considered to be lower status also did not consistently have higher prevalence rates for chronic maxillary sinusitis or rib periostitis. There were no instances where males or females were significantly more likely than the other sex to suffer from either of these conditions, although this might indicate a lack of significant difference in work activities or living environment. Furthermore, in no cases did dental disease account for the lack of significant difference between population with different lifestyles or environments, and could only be associated with less than 50% of individuals with chronic maxillary sinusitis. However, this does not mean that there is no relationship. It is possible that a) there are factors that affect a population's exposure and reaction to air pollution, such as time spent indoors or facial physiology and/or b) the difference in air pollution experienced by two populations must be much larger than the differences between most of the populations here in order to produce statistically significant differences in the prevalence of these lesions. It is also possible that the relationship between air quality and these lesions is confounded by other factors, such as the predisposition to allergic reactions. In some populations some individuals may be predisposed to these reactions and therefore have higher prevalence rates of these lesions than a population with a similar environment but fewer individuals with a propensity to have allergic reactions.

What this study does demonstrate is that researchers must be more cautious about making the assumption that if a population they are analysing has high prevalence rates for chronic maxillary sinusitis or rib periostitis, without any obviously related dental disease, this supports the theory that they were exposed to poor air quality. This link is complex, and our understanding of what is causing these lesions is not yet complete enough to make any certain connections between cause and effect. Without further research, we cannot positively make this assertion. Something airborne, such as toxic gases, particulates, or microbes, are causing inflammation in the soft tissues of the respiratory system. However, without further research it would be impossible to determine whether these are pollution, such as particulates and gases, or microbes. The effects of these airborne irritants are further complicated by the effects of the environment, such as climate, and host factors, such as predisposition to allergies.

7.1 Limitations of the research

Unfortunately, suggesting that there may be a causal link between activities and environment and medical conditions, particular those with many known causes in living populations, is often made difficult by the nature of the samples available for study in bioarchaeology, and particularly the level of preservation and the availability of associated contextual information. Were these same lesions consistently being explored in living populations, it would more likely be possible to determine whether the types of activities, the periods of time spent performing them, and the amount of time spent in environments with poor air quality had any correlation with prevalence of the conditions. In archaeological populations, particularly prehistoric and early historic populations, this information may be extremely limited or not available at all. It is in theory possible to suggest relative exposure to poor air quality, based on artefacts, ecofacts and structures recovered from nearby contemporaneous archaeological sites, including settlements, if they are preserved and excavated. However, even this may not be enough for an accurate understanding of the effects of air pollution on the respiratory health of these populations.

This research is further complicated by the availability of skeletal material. The skeletal materials available for any bioarchaeological study are those which have been excavated, not reburied, and are held in a location where access can be gained by researchers. In this study, many of the samples differed from the ideal in some way. In some cases, samples did not come from the precise background or environment that would have enabled better comparisons to be made. For example, the urban samples from London were not strictly very high or very low status, but relatively high and low status populations, and in some cases the samples were smaller than ideal for statistical comparisons, such as in the case of the lower status urban population. In other cases, there was less information about the lifestyle and environment than would be considered ideal for interpretation, as in the case of Abingdon Vineyard. These smaller differences in lifestyle, in addition to the unknown information about daily activities, could have resulted in less difference between prevalence rates for these two lesions. This, as a result, would lead to the conclusion that environment, status, and occupation has little or no effect on chronic maxillary sinusitis or rib periostitis.

Furthermore, as discussed in Section 4.1.1.2 the maxillae and the ribs are relatively fragile elements that are among the most shallowly buried when individuals are laid supine. As a result, these elements are often damaged post-mortem (Henderson 1987; Waldron 1987). In individuals where part of the maxillary sinus was missing, the absence of a lesion could not be definitive, as there could have been lesions on the parts of the sinus that were not preserved. In order to minimise this bias the approximate percentage of the sinus preserved was recorded in addition to the presence and absence data. The large sample sizes and statistical analysis would also minimise any bias caused by post-mortem damage.

In addition to damaged sinuses, complete sinuses were also problematic because it was not possible in these cases to observe the presence or absence of lesions within. In almost all cases there was sufficient damage, either to the maxillary sinus itself, or to the nasal cavity or floor of the orbit, that the endoscope could be inserted in to the sinus and presence or absence of lesions could be recorded. On the very rare occasion when there was no opening in the maxillary sinus large enough for the endoscope to fit through these sinuses were not included, as permission to drill into the sinus for many samples could not be granted.

7.2 Directions for further research

The limitations of this study, however, do not mean that these lesions should be disregarded or not recorded. Rather, it is the exact opposite. It is possible that further research could shed light on the hypothesis proposed. In order to gain a better understanding of the causes of chronic maxillary sinusitis and rib periostitis in bioarchaeology, many more populations need to be examined using the same research methodology so that the results can be compared and the data, as is the case with any bioarchaeological study, should be presented as true prevalence rates. As more research is done, the links between cause and effect could become clearer, unusual populations might become more visible as such, and similarities between these populations with unusually high or low prevalence rates may become apparent. By comparing these rates with each other, with archaeological, and with historical evidence it could be possible to determine the causes of these lesions, or the reasons for high and low prevalence rates. If we could determine the aetiology of these lesions with relatively certainty, it would provide valuable information about health, lifestyle, and/or the environment people lived in where there is none available in the archaeological or historical records. It could also provide information about allergies and localised infections which could not be recorded from skeletal remains in any other way or possibly allow us to determine what specific forms of respiratory disease people suffered from. Furthermore, if these lesions were found to be more common within families it could provide information on genetic relationships within a population. In order to do this, it is necessary that even minor manifestations of these lesions are recorded. True, not crude, prevalence rates should be recorded, as well as the nature of the lesion; whether it is active or healing, osteoblastic or osteoclastic, and where in the sinus or on the rib (or in the rib cage) the lesion is located. In the case of maxillary sinusitis, it is essential that any dental disease in the maxillary teeth that could lead to infection in the sinus or remodelling of the maxilla is also noted in order to determine the extent of its influence as well as eliminate possible confounding factors.

Few researchers have examined respiratory disease in the past, and few of these are recorded in such a way that they are comparable. Only in the last 16 years have any studies examined the lesions associated with inflammation of the respiratory system on a population level and attempted to link these conditions to the lifestyle, environment, and general health (Boocock *et al* 1995; Kelley and Micozzi 1984; Lewis 1995; Matos 2006; Merrett 2004; Merrett and Pfieffer 2000; Roberts 2007, 1994; Santos 2006). However, these studies have only begun to suggest possible future research rather than resolving the questions.

In addition to examining many more populations overall, and in order to examine the role of air quality further, it would be beneficial to examine populations known, without question, to have been exposed to extremely high concentrations of air pollution and compare them to nearby populations exposed to average amounts. Often individuals who specialised in a particular occupation will live near their work or where resources are most available. In some cases artisans will group together in order to make the acquisition of resources more economical. For example, a community of individuals such as miners, bakers, potters, or metalworkers buried together, to the exception of the rest of the community. If this information about occupation is known, the skeletal population could then be compared with nearby rural or urban populations in order to determine whether individuals who frequently performed these activities also had higher prevalence rates for chronic maxillary sinusitis or rib periostitis. This comparison would have to be repeated multiple times in order to determine whether there is a true relationship between the occupations and lesions representative of respiratory disease. Then the question of poor air quality as a cause for respiratory disease in the past could be supported or possibly ruled out. It is also necessary that other causes be more thoroughly examined.

An examination of the clinical literature provides a long list of known causes of both upper and lower respiratory disease. It is possible that examination of skeletal remains, even with good contemporary historical records, will never be able to examine some of these causes. However, there are others that could be researched further, for example associations with dental disease, an inherited predisposition, morphology of the sinuses, and the immune response.

Brook (2006) suggests that 40% of cases of chronic maxillary sinusitis in living populations are of dental origin. It is apparent from the results of this study that severe dental disease, which causes the maxilla to remodel, and not just abscesses with drainage sinuses leading directly into the maxillary sinus are linked with higher prevalence of chronic maxillary sinusitis. Perhaps an examination of the correlation between the overall prevalence of dental disease and the prevalence of chronic maxillary sinusitis in a population will lead to a better understanding of this link. In this study there were 891 sinuses with chronic maxillary sinusitis of which 438 (49.16%) had associated dental disease in the maxilla. This is higher than suggested by Brook, but there is no way to determine whether the dental disease is the cause or just coincidentally found in the same individual, on the same side of the maxilla, as there is always the possibility that the chronic maxillary sinusitis predated the dental disease. However, given that dental disease could only account for just under half of the chronic maxillary sinusitis seen, it is understandable why populations with dental disease did not have a significantly higher prevalence rate when compared to the portion of the population without dental disease, who made up just over 50% of the cases of chronic maxillary sinusitis. Whether this is also the case in other populations from different environments needs to be examined further.

It is also worth examining the effects of heredity and overall health. The lesions on the bones surrounding the maxillary sinuses are caused by inflammation of the soft tissue. Under normal circumstances, the immune system does not need to be directly involved with the elimination of microorganisms or particulates in the sinuses (Jones 2001). However, there are a number of clinical articles that have suggested that chronic maxillary sinusitis is caused by malfunction of the immune system, which can react without a sufficient cause (Chen *et al*. 2003; Davis and Kita 2004; Kern *et al*. 2008; Steinke and Borish 2004). If this is the case, then the overall number of lesions in their skeleton might be expected to be higher in these individuals. However, this needs much more research and, given that individuals who are less healthy and possibly more likely to immunologically overreact to small health threats are more likely to die before the skeleton remodels, the osteological paradox could confound the results of any study which attempted to research this question (Wood *et al*. 1992).

In the case of infections localised to the upper respiratory system it would be worth examining the link between lesions in the maxillary sinuses and lesions associated with inner-ear infection, such as in the case of otitis media and mastoiditis. As a localised infection would leave no other indication in the skeleton, unlike in the cases of systemic conditions like leprosy or tuberculosis, there would be no way to diagnose this aside from the absence of any other diagnostic lesions. Given the connection between the inner ear and the upper respiratory system, and the likelihood of infections spreading between them, if there was a correlation between these, this would be strong evidence that localised infections are a common cause of these lesions.

To the same end, it would be beneficial to determine whether there is a link between the rate of chronic maxillary sinusitis and an inherited predisposition, if the tendency of the immune system to overreact is more common within families (Maksimovic *et al*. 2010). Given that cemetery samples from the Iron Age that were studied here might have been made up of a number of small families (Hey *et al*. 1999), if the population were more likely to be related to each other than in any other cemetery population, this could explain the relatively high rates of chronic maxillary sinusitis. This would be difficult to test. If a population were known to be closely related, for example if a relatively recently buried cemetery population whose names and family relationships were known were examined, it could be possible to see whether there is a higher risk within some individual families. In this study, St. Bride's Crypt was examined and there were some individuals who were known to be related by blood (rather than by marriage). However, as the crypt was in use for such a short period, multiple generations of families were rare. If there were a population with multiple generations of many unrelated families, and if the prevalence amongst the families were compared with each other, it might be possible to determine whether there was a relationship between heredity and chronic maxillary sinusitis, or even rib periostitis.

It would also be useful to gain a better indication of the meaning of the severity of the lesions, and by extension the inflammation that caused them. It is possible that certain causes are more likely to lead to severe lesions while others only lead to minor ones. If possible, an objective, or as objective as possible, scale of severity should be created so that chronic maxillary sinusitis is not just being recorded as present or absent but also with regard to its severity, as this might provide more of an indication of cause than presence alone. If this scale could be proved to have low inter and intra observer error it could be a valuable tool. It was mentioned in Chapter 2 that Giacci (2001) found even among their control group of three individuals, 60% had some form of remodelling on their ethmoid sinuses associated with sinusitis, although it was less severe than in those who had complained of, and been diagnosed with, sinusitis. While this is an extremely small sample and the results could be coincidental, if this is the case it is possible that many of the individuals recorded as having sinusitis in this study, who showed very little remodelling, were never symptomatic or not to the extent that it would be considered problematic by the standards of living populations. A scale could be based on the number and or relative size of the area in the sinus affected. For example, one group could be below 25% of the sinus affected, and then 25%-50%, 50%-75% and 75% or more. However, this scale would have to adjust to account for how much of a sinus is preserved.

It would also be very useful to examine more individuals from populations whose health and lifestyles are well known in order to clarify all the possible causes of respiratory disease. Similarly, although it would be difficult ethically, and costly, in order to gain a better understanding of the link between bioarchaeological and clinical frequency rates, it would be interesting to examine these lesions using living populations. A study could compare living individuals diagnosed with upper and lower respiratory disease and a control group of those not diagnosed with any respiratory conditions, and examine the individuals using radiography to determine whether there was any bone remodelling.

It might also be useful to determine whether there is a link between the overall size or shape of the maxillary sinus and the likelihood of developing chronic maxillary sinusitis. If chronic maxillary sinusitis is more likely to develop in smaller of narrower sinuses this could also confound the results of this study. As there are no anatomical markers to get an objective measurement of the size or volume of the sinus, particularly as they are frequently broken post mortem, it might be possible to calculate the sinus volume of complete sinuses using CT scans (Ikeda 1996; Rae and Koppe 2000). Once the volume was calculated, the sinus could then be examined using an endoscope to determine whether there was evidence of chronic maxillary sinusitis (as done by Wells, 1977).

7.3 Conclusion

Respiratory disease is among the most common causes of morbidity and mortality in living populations; in particular in developing countries where technology such as open fires and antiquated stoves are still regularly in use. On this basis, it is not unreasonable to expect the populations in the past, who used similar technology, would be equally susceptible to respiratory diseases correlated with technologies in living populations.

However, as this study has shown this link is more complex than the previous research has hypothesised. There are multiple factors relating the domestic, occupational, and general atmospheric environments, as well as host factors that can alter the prevalence of respiratory disease significantly. Without more research and TPRs for both chronic maxillary sinusitis and rib periostitis from populations all over the world these relationships will remains unclear.

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